ECOSTUD BUILDING SYSTEM

September 1983

Prepared By:

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The views and conclusions expressed and the recommendations made in this report are entirely those of the authors and should not be construed as expressing the opinions of the Alberta Department of Housing.

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DEPARTMENT OF HOUSING

Innovative Housing Grants Program

ECOSTUD BUILDING SYSTEM

David F.Begin, P. Eng.

Introduction

The concept of the Ecostud Building System was developed to allow for increased insulation levels required to provide more energy efficient housing. It is an alternative to double stud walls and other framing systems. The Ecostud is almost as simple as conventional stick framing while providing insulation levels similar to double stud walls.

System Concept

The Ecostud is in essence very similar to a roof truss. The stud is constructed from two vertical wood members separated by 38 x 89 mm. spacers. The load bearing member, (referred to as the major stud) has minimum dimensions of 38 x 65 mm; and the other stud, referred to as the minor stud, has minimum dimensions of 38 x 65 mm. The major and minor stud and wood spacers are tied together with 38 x 75 mm truss plates.

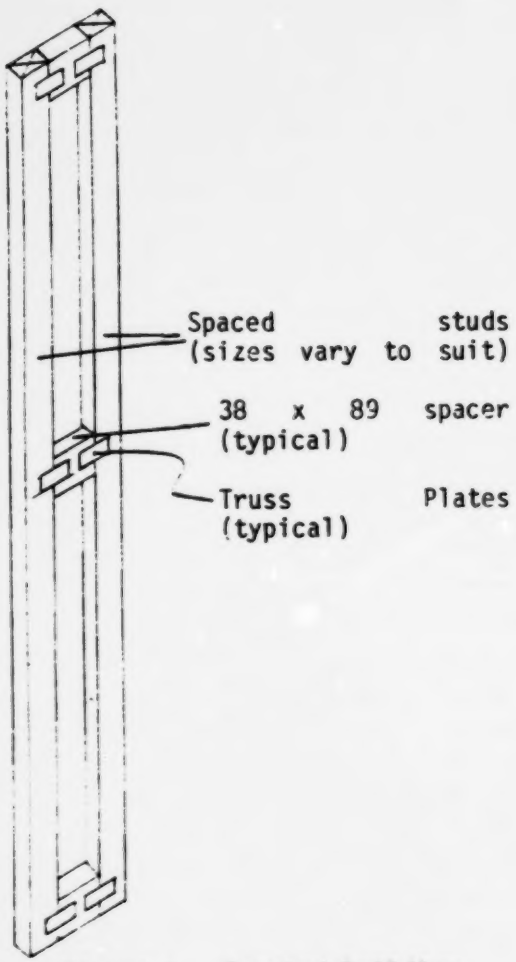

Figure 1. Ecostud Building System

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Structural Design

Preliminary structural analysis indicates that the load-bearing capacity of the Ecostud constructed out of the 38 x 65 mm major stud and the 38 x 65 minor stud may be equivalent to the standard 38 x 89 mm stud. The Ecostud has the potential to handle increased structural loads when the sizes of the major and minor stud are increased, but this will be the subject of further research and actual testing.

Framing Details

Framing details were developed for a house using the Ecostud Building System, to demonstrate and test the application of the Ecostud. The demonstration project confirmed that this system is a fast and efficient method of incorporating more insulation into wood frame walls. Additional benefits of this system are relatively easy vapour barrier details and reduced labour cost for electrical wiring as fewer holes have to be drilled.

Cost Comparison

Preliminary cost evaluations of nine different wall-framing systems indicate that the Ecostud is one of the most cost effective systems.

Conclusions

The analysis and research carried out so far indicate that the Ecostud is a viable construction method for framing wide walls to allow for increased insulation levels. More rigorous structural analysis and testing will be carried out to obtain regulatory approvals for the framing system.

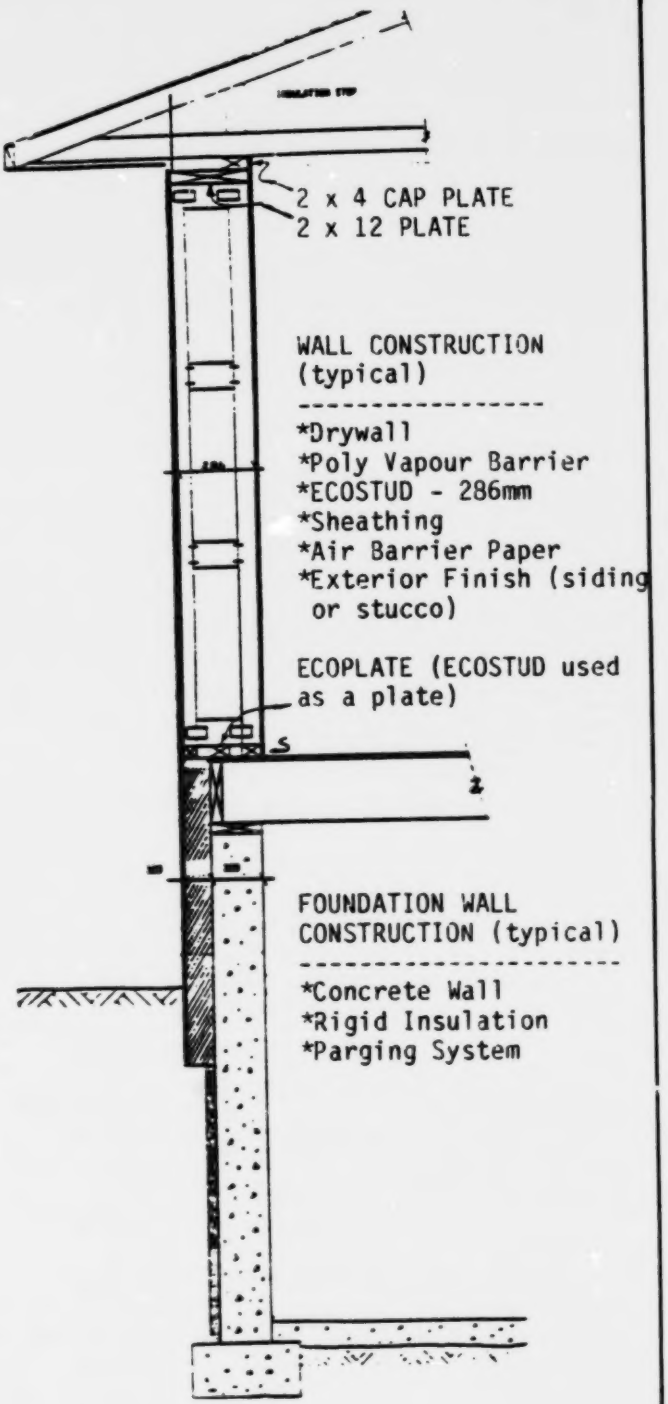

Figure 2. Ecostud Building System (typical)

FOREWORD

This study was made possible with funding provided by the Innovative Housing Grants Program of the Alberta Department of Housing. Originally conceived in 1978, the Program is intended to encourage, sponsor, and assist research and development in the fields of housing, site and subdivision design, energy conservation, site servicing and urban development. Generally, the aims of research funded by the Innovative Housing Grants Program are to reduce housing costs, increase the supply of appropriate housing or improve the utility or performance of dwelling units or subdivisions.

The main purpose of funding these studies is to examine the current issues in the field of housing and to develop innovations which offer improvements. Comments and suggestions regarding the information contained in these reports are welcome.

Innovative ideas come from a wide variety of applicants such as builders, developers, consulting firms, industry associations, municipal governments, educational institutions, non-profit groups and individuals. As the type of project and level of resources vary from applicant to applicant, the resulting documents are also varied.

Where possible the Department encourages the dissemination of study results under a standard cover and in a uniform format. This study, Ecostud Building System, was completed in June 1983 and subsequently released under a different cover.

Please send comments and suggestions or requests for further information to:

Innovative Housing Grants Program
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Edmonton, Alberta
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September 1983

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My thanks goes to God who has granted relationships with people; some of these people have expertise and experience that have added much to my working knowledge and enabled me to complete this study. Others have been able to accomplish tasks which I did not have time or experience for.

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-to his son Claude Rekken for drafting the plans, spearheading construction and together with a classmate John Neiman conducting the basic cost comparison calculations;
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PART A - ECOSTUD BUILDING SYSTEM

1.0 INTRODUCTION

1.1 PURPOSE

The purpose of the Ecostud is to incorporate the new higher standards of insulation within the wood frame wall while minimizing labour and material costs.

1.2 SCOPE

This report studies the Ecostud concept on a general basis with a simplified analysis and design based on the spaced stud design covered by the CSA 086 and the Alberta Building Code (ABC). The validity of the analysis will be verified in a follow up study which will focus on the structural analysis and the testing of the Ecostud. The structural analysis will be carried out by an established structural engineering firm.

1.3 BACKGROUND

This report is in fulfillment of a grant contract under the Innovative Housing Program of Alberta Department of Housing.

The author as a professional engineer has been involved in the design and construction of residential and commercial buildings for several years. The idea was born as a result of recognizing the need for an exterior wood frame wall system which would simply and effectively incorporate adequate insulation.

2.0 ECOSTUD

2.1 DESCRIPTION - see Drawing 1 and Table 1

The Ecostud is a double member stud that replaces the standard 2x4 stud in light framing wood construction. It is composed of two vertical members which are separated and connected by 2x4

spacers. The vertical member which carries the roof load directly is refered to as the major stud; the other member as the minor stud. The spacers are from 2x4 lumber and the spacing is dependent on the size of the minor stud and on the distance required between lateral supports. The connections between the vertical members and the spacers are made with trussplates.

2.2 SPACERS

As described above, the spacers which separate the major stud and minor studs are cut from 2x4 lumber. The 2x4 provides the minimum width necessary to maintain the risidity of the connection.

2.3 CONNECTORS

The spacers and the minor stud and major studs are connected with metal trussplate connectors on both sides; this is also a requirement of the ABC section 9.7.1. The trussplate connector has integrally attached nails which are punched from the metal plate. The use of other types of connectors such as nails and glue was researched but the trussplates provided the best connection for a moderate increase in cost.

The trussplates can transfer both shear and tension. Due to the high strength of the trussplate connection, the smallest size of trussplate is adequate for most Ecostud applications. Two sizes are available depending on the manufacturer; 38x75mm or 25x100. Truswal, which supplies the 38x75 size, rates their connection at 35kg per mm (400#/inch) of width in both shear and tension.

2.4 WIDTH OF ECOSTUD - see Table 2

The overall width of the Ecostud can be varied to meet specific insulation requirements. The proposed widths may conform to the standard width in which full dimension lumber is available: 140, 184, 235, 286mm or to metric dimensions: 150, 200, 250, 300, 350, 400mm, etc. When metric dimensions are used, then plywood must be used for rough framing of windows and doors.

The recommended width for residential construction is 286mm or 300mm. This width will accomodate a range of fibreglass (FG) insulation levels:

-2 RSI 3.5 (R20) FG batts => RSI 7.0 (R40) or

-RSI 3.5+2.1 (R20+R12) FG batts => RSI 5.6 (R32).

Insulation is covered in greater detail in section 5.0.

2.5 TYPES OF ECOSTUDS - see Table 1

The Ecostud members can be designed to accomodate various loads and uses. The coding system used to describe the various Ecostuds is based on the pre-metric description of lumber. For example the Ecostud ECS-2:3 would have a a 2x2 minor stud and a 2x3 major stud. Table 1 shows the range of studs and the spacing of the 2x4 spacers.

3.0 DESIGN

3.1 STANDARD WALLS - Table 4

The structural capacity of standard walls 2x4, 2x6 were evaluated in order that a comparison could be made between the standard stud walls and various Ecostuds. The column capacities of standard stud walls are shown in Table 4.

3.2 STRUCTURAL COLUMN DESIGN see Table 3

The Ecostud is a unitized structural unit that can be analysed as a spaced-column. This type of design is covered in the building code CSA-086 - section 3.4.2.3. The Ecostud when analysed as a spaced-column is substantially stronger than the sum of the major and minor studs when they are considered individually. This is due to the rigid connection of the spacer between the studs which provides mutual support between the major and minor studs. The design calculations for the spaced-column are included in the Appendix AA-1. These calculations include the load-sharing factor of 1.1 which is covered in clause 4.3.1 of the CSA 086. Table 3 will show the column capacities for Ecostuds of standard metric stud length 2290mm in another report, subsequent to this report.

3.3 ECOSTUDS - MAJOR STUD BEARING SINGLY AND FULL BEARING

The Ecostud can also be designed to bear on the major stud only or both the major and minor studs. The Ecostud wall in the former case can cantilever the foundation wall and bear solely on the major stud; see Drawing 2. The advantages of this feature are covered in section 4.2.

3.4 BEAM-COLUMN ANALYSIS

The Ecostud has not been designed for bending but preliminary analysis has shown it has sufficient strength in the connections to cantilever from the interior stud and carry the weight of a stucco wall. The Ecostud will be analysed as a Veerandahl truss in the subsequent study to determine the bending capacity of the Ecostud and to confirm the adequacy of the Ecostud to resist bending loads imposed by eccentric forces due

to cantilevered exterior finishes and/or wind. To provide full beam action, diagonal connections would have to be provided between spacers and the costs would increase substantially.

> NOTE: The Ecostud is designed to be used principally as a column. The strength of the Ecostud as a beam is low when compared to equivalent dimension lumber but is assumed to be adequate to resist wind loads. Further research of the beam strength will be carried out in the subsequent study. For more discussion of wind loads, see respective section.

3.5 COMPARISON - ECOSTUD AND STANDARD WALLS

The Ecostud ECS-2:3 compares favourably with the standard 2x4 wall in strength. In single bearing on the major stud it is essentially the same and in double bearing it is marginally stronger. The Ecostud ECS-2:3 would thus meet the majority of housing requirements in the building construction industry.

3.6 PREFERRED SECTION - ECS-3:3 see Drawings 1 and 2

It appears that the Ecostud ESC-3:3 may be as economical to produce as the Ecostud ESC-2:3. The Ecostud ESC-2:3 has a smaller minor stud but the cost saving is lost with the additional spacer and trussplates that are required to stabilize the 2x2. The ECS-3:3 is also stronger and has a better user appeal; thus the Ecostud ESC-3:3 would fulfil the majority of both the residential and commercial markets.

4.0. FRAMING DESIGN

The Ecostud building wall system typically uses the standard method of wall construction single bottom plate, double top plate, stud spacing of 400 or 600mm o/c, etc. The stud spacing of 400mm is usually used because it provides better support for the gypsum drywall.

4.1 PLATE SYSTEMS (PS) - TOP AND BOTTOM - see Table 6

Alternative methods of framing were considered but the conventional framing system using single bottom, double top plate and standard stud length was selected as the best since builders will not have to learn new construction techniques.

The ABC, see section 9.10.15., requires that firestops be at floor, ceiling and roof levels in all walls. There is some question as to whether a firestop is required at ceiling level for single family residential construction or for balloon framing, with various professionals expounding differing viewpoints. This will be addressed in the subsequent study; for the purposes of this report, it is assumed that a firestop is required.

A firestop may consist of the following:

sheet metal	- 0.91mm
asbestos board	- 6mm
gypsum board	- 12mm
plywood	- 12mm with joints backed
lumber	- 2- 19mm with joints overlap
lumber	- 38mm

The sheet metal and asbestos board on preliminary analysis were too expensive and were eliminated. Table 6 shows the various plate system combinations which maintain the standard stud length. For the systems shown, the plywood floor provides the floor level firestop. Other combinations are used to form the ceiling level firestop. PS #3 is shown in Drawing 4 which uses an Ecoplate (an Ecostud laid horizontal) for the first top plate with a drywall firestop or possibly a metal sheet. PS #1 is shown on Drawing 3. PS #1 and 3 are considered the most viable options based on labour and material costs. PS #2 is the most economical if no firestop is required at ceiling level.

The behaviour of the Ecoplate under wind loading conditions is discussed in section 4.6.

4.2 MAJOR STUD OR BOTH STUDS IN BEARING

The Ecostud can bear on the floor joists in the traditional manner for the full width of the wall or it can be designed to bear only on the major stud. In the latter, the Ecostud wall cantilevers the foundation wall (see Drawing 4); this feature provides two direct benefits:

1-The concrete can be insulated from the exterior; see Drawing 3. This places the concrete within the insulated building envelope, enabling the concrete to serve as a heat retention mass.

2-A continuous poly vapour barrier can be installed around the joist header; see Drawing 4. This feature enables a continuous vapour seal of the building, a standard requirement in energy efficient house design.

4.3 BASE PLATE BEARING DESIGN - Table 5

The allowable bearing pressure of wood perpendicular to the grain is approximately half or less of the allowable bearing pressure parallel to the grain. Conventional walls of 2x4 have the full 89mm width to bear on. The Ecostud Building System using ECS-2:3 maintains approximately the same column capacity as a conventional wall but the bearing width on the plate is only 64mm, a 25% reduction. When higher bearing capacities are required either full dimension lumber can be used for the base plate or an Ecoplate with a wider major stud, such as the ECS-2:4. With the wider plate, the bottom spacer also transfers load to the base plate. Therefore in Ecostud design, due to the high capacities of the slender vertical bearing members, the bearing capacity of the plate should be checked and increased

when necessary.

4.4 WINDOW AND DOOR FRAMING

The rough framing for windows and doors can be formed in one of two ways:

1-with full dimension lumber corresponding to the width of the wall, see Drawing 4, or

2-with 2x4 peripheal framing covered with 12mm plywood.

For wall widths corresponding to 2x8 and 2x10, full dimension lumber is more economical; for 2x12 wall widths, both methods can be used. For walls not corresponding to standard lumber dimensions, plywood would be the most economical alternative.

4.5 BALLOON FRAMING

The Ecostud is not subject to warping due to the rigidity and the close spacing of the trussplate connections. Balloon framing has not been used in Alberta and one reason is that spruce lumber tends to warp when long narrow lengths are used, eg. 2x4 and 2x6's longer than stud length. The stability of the Ecostud makes the Ecostud system very suitable for framing the high continuous walls which are required for cathedral construction, for commercial building construction or for balloon framed systems.

4.6 LATERAL BRACING

In the case where the vertical loads are carried by the interior stud, the lateral stability of the interior studs must be ensured. Horizontal steel strapping at the third points for stud height walls will provide this stability.

4.6.1 WIND BRACING - WITH STRUCTURAL SHEATHING

In standard walls, the exterior sheathing provides the lateral bracing against wind forces. In the Ecostud System when both major and minor stud are in bearing, the exterior sheathing will likewise provide the required lateral bracing. In the case of the cantilevered Ecostud which bears only on the interior major stud, the exterior sheathing is not directly attached to the bearing stud; therefore the transfer of these forces to the interior stud must be considered. Both the top full plate and the Ecoplate bottom plate will tend to transfer these loads. It is assumed that the Ecoplate has adequate strength in it's connections to transfer these loads and further study will be carried out to ascertain the best method of bracing the Ecostud framing system.

4.6.2 WIND BRACING - ELIMINATION OF STRUCTURAL SHEATHING

To reduce costs, exterior structural sheathing can be eliminated or replaced by non structural sheathing. The wind bracing can then be provided by steel strapping on the interior major stud, running diagonally across the wall from top to bottom in both directions. Such replacement of the structural sheathing with steel cross-bracing promises to substantially reduce wall costs and and assessment of the actual savings will be included as part of a subsequent study.

4.6.3 BRACING SUMMARY

In the case of bearing on the interior stud, horizontal steel strap bracing is required for lateral stability of the major stud.

In addition, when there is no structural exterior sheath-

ing, diagonal steel strapping across the wall from top to bottom is required. The type and schedule of such bracing will be part of a subsequent study.

4.7 WIND UPLIFT ANCHORS

In conventional wall framing, the exterior plywood sheathing serves to anchor the walls to the foundation. In Drawing 2, this type of anchorage is not available: lengths of steel strapping can be used at regular intervals to secure the studs to joist header.

5.0 INSULATION POTENTIAL - see Table 2

The Ecostud wall is typically filled with fiberglass (FG) batt insulation which is the most economical insulation material available meeting the ABC standards. The wall cavity should be entirely filled to prevent chimney effects in the wall both for fire protection and to minimize heat loss (from convective air circulation in the wall). Any suitable combination of batts can be used to fill the wall space: for example in a 286mm Ecostud wall, various combinations of batts can be used to fill the cavity, ie RSI 3.5 + 2.1 (R20 + 12) or two RSI 3.5 batts. The insulation value of a 286mm wall can be made to vary between RSI 5.6 & 7.0.

The cavity within the actual Ecostud, between the spacers, also requires insulation as the standard width insulation will leave a gap. To fill this void, two methods are possible:

1-the 400mm FG batt, which is available for steel studs, can be used: at spacer locations the batts can be cut to allow insulation to fit around.

NOTE: This method has been field tested and the batts tend to crumple next to the studs and leave a void which reduces the

effectiveness of the insulation. This extra insulation could be cut partially away but would probably be labour intensive or,

2-the standard 375mm FG batts can be placed and the gap in the Ecostud can be filled with strips of insulation. For a 286mm wall with Ecostud ECS-2:3, the gap is approximately half the batt width. Half widths can be cut and peeled off in thirds to fill the Ecostud cavity.

6.0 ADVANTAGES

The Ecostud exterior wood frame wall has several advantages:

1-Insulation can be increased while still framing only one wall.

2-Thermal bridging of the wood wall is reduced from 9.9% to 1.1% of the wall surface area compared to single stud methods.

3-Framing time is reduced for cathedral and balloon framing.

4-The openings in the Ecostud System together with the optional cantilever and balloon framing features can significantly reduce labour time for electrical installation.

NOTE: Also the possibility of nails and screws piercing electrical wire during construction is eliminated since the wire can be placed at the center of the framing space.

5-The hollow in the Ecostud allows the priviledge if necessary of installing plumbing and heating systems in the exterior walls.

6-The exterior wall can overhang the concrete foundation wall. This allows the concrete to be insulated from the exterior and the mass of the concrete remains within the insulation envelope and serves as a heat retention mass.

7-The basic method of framing a wood wall remains the same.

8-Windows have a large interior sill.

7.0 MARKET POTENTIAL

7.1 EXTERIOR RENOVATIONS

The Ecostud ECS-2:2 can be used for renovations to add insulation and a new recessed vapour barrier can be incorporated at the same time. For this new exterior wall 600mm spacing of the studs is adequate.

7.2 RESIDENTIAL HOUSING

The Ecostud ECS-2:3 as previously discussed has a strength comparable to the conventional 2x4 wall and could fulfill a majority of this market although as previously stated the ECS-3.3 should also be a cost effective alternative.

7.3 MULTI-FAMILY HOUSING

For multi-floored buildings such as apartments and condominiums, balloon framing sould be considered as a practical way to ensure a tight vapour/air barrier and reducing labour and erection time.

7.4 COMMERCIAL-INDUSTRIAL BUILDINGS - WAREHOUSES

The Ecostud ECS-3.3 and larger can be used to balloon frame walls of 6m in height or more. A cost advantage would be possible because of reduced erection time and reduced labour, compared to platform framing and block wall construction while achieving the same performance.

7.5 MISCELLANEOUS INTERIOR AND EXTERIOR USES IN WALLS

The Ecostud can be used for plumbing walls, for plenums and for separation walls between residences in multi-family type construction. In plumbing walls, an ECS-2:2 of 150 or 180mm width would facilitate plumbing installations. For common walls in Multi-family housing, an ECS-4:4 should have an equivalent sound

rating to double or staggerred wall construction, at a reduced cost. Plenums and chimneys can be also framed into Ecostud interior walls.

8.0 MANUFACTURE

8.1 MATERIAL SELECTION

The tendency of slender lumber such as 2x2 and 2x3 to warp is well known. The Ecostud assembly, formed by mechanically connecting 2x2 and 2x3's, resists warping, allowing the use of material with "partial air dry" (PAD) moisture content instead of kiln-dried (KD) material.

There is some question as to the availability of 2x3 material and whether it is more economical to use 2x4's instead of 2x3's. Recent contact with truss manufacturers has confirmed the price of 2x3 material is low enough to warrant using it and there isn't at this time a problem of supply.

8.2 ASSEMBLY

The Ecostuds and the Ecoplate can be assembled with machinery that is presently used in truss plants. C-clamps or a rolling press will press the trussplate connectors firmly in place.

8.3 PRODUCT SELECTION

Market research is to be carried out to investigate the most popular range of widths. It is projected that these would likely be 184, 235 and 286mm. The stud length would be metric primarily. The longer lengths for balloon framing and for Ecoplate would conform to standard lengths available in the lumber industry although by proper attention to splice locations, longer lengths of Ecostud are practical.

8.4 COST OF MANUFACTURE

Preliminary cost studies have been made and a tentative cost of $2.13/lineal metre ($0.65 per foot) has been estimated for initial production. A production cost from a truss plant was also comparable to the above figure. Once a market has been established these costs should be lowered substantially, possibly as low as $1.31/lineal metre, ($0.40/foot).

9.0 SUMMARY

The Ecostud system was developed as a result of the need for adequate insulation in wood frame construction. The Ecostud is essentially assembled in the same manner as a roof truss. It is constructed from a major stud and minor stud which are separated by 2x4 wood spacers; the connection of the spacers and the studs are with 25x75 mm trussplates. The Ecostud ECS-2.3 is adequate for most residential applications and is composed of a 2x3 major stud and a 2x2 minor stud. It has a load capacity comparable to the standard 2x4 stud.

The Ecostud framing system has several advantages:

1-The optimum depth of insulation can be selected at the builders perogative.

2-Thermal bridging in wood wall is reduced to a negligible quantity since the spacers only form a small portion of the wall area.

3-The hollow in the Ecostud allows ease of installation of electrical wires and plumbing in walls.

4-The Ecostud wall can overhang the flooring which allows a continuous vapour barrier to be placed.

5-Overhanging the floor enables the concrete to be insulated from the exterior which allows the concrete to serve as a heat retention mass.

6-Interior window sill of usable depth is now available for setting plants, books, etc.

7-The system uses the same framing practices that have been developed in the construction industry and successfully used for many years.

8-Ecostuds can form continuous vertical walls of 6 metres or more that are required in cathedral, open beam, balloon framing and commercial-industrial construction with significant savings in cost of material and labour.

9.1 CONCLUSIONS

The preliminary analysis and research shows that the Ecostud concept is a viable method of constructing a wide wood frame wall to increase the wall insulation. The Ecostud wall is also adequate to carry the standard roof loadings.

The structural design is based on the CSA 086 and the assumption is made that the Ecostud functions as a spaced-stud. The strength of the Ecostud is a function of the size of the vertical studs, spacers and the connectors. A more rigorous structural analysis and testing should be done:

-to prove the spaced-stud action assumption;

-to determine the actual strength as a beam-column (combined bending and compression);

-to analyse the system under wind load conditions.

This analysis and testing program should be adequate to obtain systems approval with Alberta Building Standards and the testing program is required for evaluation by CMHC. Once these approvals have been obtained, marketing on a larger scale will be possible.

REFERENCES

Gilbert M. Rekken, P. Eng.; G.M. Rekken & Associates,
Consulting Engineers, Edmonton, Alberta

Edward Freundlich, P. Eng.; G.M. Rekken & Associates,
Consulting Engineers, Edmonton, Alberta

BIBLIOGRAPHY

ALBERTA BUILDING CODE - 1981

CSA 086 1970, 1980M

TIMBER DESIGN MANUAL - 1972

MERCHANT FACTS - STELCO - 1974 nail info

APPENDIX AA-1

REFERENCES TO ALBERTA BUILDING CODE

GLOSSARY OF TERMS

GLOSSARY OF ABBREVIATIONS AND SYMBOLS

SPACED-COLUMN ANALYSIS

- ALBERTA BUILDING CODE -
REFERENCES WITH COMMENTS RE: ECOSTUD

1.0 FIRE STOPPING

-9.10.16 -single family residences
-3.1.9 -multiple tenancy
-9.10.15 The code requires that firestops be at floor, ceiling and roof levels in all walls. A firestop may consist of the following:

sheet metal	- 0.91mm
asbestos board	- 6mm
gypsum board	- 12mm
plywood	- 12mm with joints backed
lumber	- 2- 19mm with joints overlap
lumber	- 38mm
rockwool	- pending approval

2.0 MINIMUM DIMENSION OF WALL FRAMING LUMBER

-9.23.10.1 minimum dimension 2x3 for standard walls
-This clause is used primarily because of warping and stability.
-The Ecostud is of truss-type construction and the connections have the strength to resist warping forces that occur as the moisture content of the wood changes, see section 4.5.

3.0 OVERHANGING WALL

-9.23.11 - -states that only one third of plate shall overhang in a wall system.
-In the Ecostud, the major stud can be considered to be the only area bearing with the result that all the remainder of the stud can overhang.

4.0 LOAD SHARING

-4.3.4 -

GLOSSARY OF TERMS AND SYMBOLS

FRAMING SYSTEMS AND LUMBER - TERMS

Balloon framing	-continuous vertical wall framing, from which floors are hung after wall is erected;
Cap plate	-the second top plate used in framing a stud wall;
Cathedral framing	-a framing system which uses beams to form a pitched roof, the ceiling is finished to the bottom of the beams which gives a pitched ceiling on the interior also;
Platform framing	-the conventional system of framing in Canada, each floor bears directly on the wall system below;
Ecostud	-a truss stud composed of two vertical members separated by 2x4 spacers and fastened together with truss-plates;
Ecoplate	-an Ecostud used as a plate in framing a wall;
KD	-kiln dried lumber, see CSA 086;
Major stud	-the larger vertical member of an Ecostud;
Minor stud	-the smaller vertical member of an Ecostud;
PAD	-partial air dried wood, same as S-DRY;
Plate	-top and bottom horizontal framing members of a wall;
PS	-a plate system used to hold the vertical studs in a wood frame wall;
S-DRY	-air dried wood, same as PAD, see CSA 086;
S-P-F	-Spruce, pine, fir; species groupins of wood in CSA 086;
Spacer	-the members separating the major and minor vertical members of an Ecostud;
Spacer block	-same as spacer, used in CSA 086 in spaced columns section;
Spaced Column	-two columns which are integrally attached to one another for mutual support.

ABBREVIATIONS

A	-area
Ck	-slenderness ratio constant designating separation between intermediate and long columns
D	-Design load
dx	-width of member with respect to the x-axis
dy	-width of member with respect to the y-axis
E	-modulus of elasticity
ECS	-Ecostud
Fc	-design bearing pressure
Fc'	-design bearing pressure modified
Fc⊥	-design bearing pressure perpendicular to the grain
FG	-fibreglass
g	-acceleration due to gravity
K	-slenderness ratio
L	-length
L/d	-slenderness ratio
Le	-effective length
MF	-modification factor
mm	-millimeter
o/c	-distance between the centers of two members, (on center)
P	-allowable load
Pc	-design connector capacity
Pf	-actual connector capacity
Pj	-allowable load major stud
Pn	-allowable load minor stud

CALCULATIONS

SPACED COLUMN ANALYSIS -CSA 086-

Ecostud assumed to act as a spaced stud

Constructed from:
- -major and minor stud of spruce lumber,
- -spacers from 38x89 mm spruce lumber at 750 mm spacing,
- -truss plate connectors both sides of all connections.
- -Lumber - Standard grade - S-P-F
  E = 7500 from table 6-7 MF = 1.0
  Fc = 4.6 " MF = 1.0 for 38 x 38

CSA 086

9.2.1.5 DESIGN OF TRUSS PLATE FASTENERS

9.7 TRUSS PLATES - DESIGN OF JOINTS

9.7.1 plates on opposing faces are identical & directly opposite to one another

9.7.3 Determination of Allowable Loads

9.7.3.1 load evaluation of truss plates according to CSA S347

9.7.3.2 design shear and tension = tested value/2.5

SPACED COLUMN section 3.4.2.3

3.4.2.3.1 The maximum permissable load for the spaced column equals the allowable unit stress x total cross sectional area of the individual members.

$$P = Fc'(A1 + A2)$$

3.4.2.3.3 Fixity Class for end spacer block
condition "a" - centroid of connector shall be within 1/20 of column length from the column end,

3.4.2.3.4 Minimum Strength of Connectors in end spacer blocks

3.4.2.3.5 Maximum Load Short Columns
- -slenderness ratio of individual member > 10

3.4.2.3.6 Maximum Load Intermediate Columns
- -slenderness ratio of an individual member > 10 < Cka

3.4.2.3.7 Maximum Load Long Columns
- -slenderness ratio exceeds Cka

Design for stud length 2290 mm Ecostuds ECS-2:3

4.3.4 Load sharing factor = 1.1

3.4.2.3.3 Fixity Class is "a"
- L/20 = 2290/20 = 114 > 89 mm - width of spacer block

3.4.2.3.4 End spacer - connector capacity - Pc
-for minor stud L/d = 2290/38 = 60.3 => table 5 - 1.85
- Pc = 38 x 38 x 1.85 = 2670 Mpa
Fastener capacity from manufacturer = Pf = 400# per inch width
Pf =400/2.2 x 9.81 = 2676 Mpa/ 38 mm width
therefore fastener capacity adequate

Type of column ? short, intermediate, long

Cka = 0.93 (E/Fc)0.5
=0.93 (7500/4.6)0.5 = 37.5

Fc' = allowable bearing strength
Fc' = 0.582 E (d/L)(d/L) =
= 0.582 x 7500 x 1/60.3 x 1/60.3 = 1.200

Pn = Fc'x A = 1.1 Fc' A / g -where 1.1 is the 10% load sharing factor
=1.2 x 38 x 38 x 1.1 / 9.81 = 194 kg

Major stud analysed as a spaced column

NOTE:- this assumption is contingent on the fact that the lateral support provided by the minor column is adequate, further research to be done in subsequent contract.

$$Cka = 0.93 \sqrt{E/Fc} = 0.93 \sqrt{7500/4.6} = 37.5$$

L/d = 2290/ 64 = 35.8

therefore intermediate column 10 < L/d < Cka

$$Fc' = Fc \left[1 - \frac{1}{3}\left(\frac{L}{Cka\ d1}\right)^4\right] = 3.27$$

$$Pj = \frac{1.1\ Fc'\ A}{g} = \frac{1.1 \times 3.27 \times 38 \times 64}{9.81} = 892 \text{ kg}$$

Total load capacity = P = Pn + Pj
=194 + 892 = 1086 kg

APPENDIX AA-2

TABLE 1 - ECOSTUD TYPES

TABLE 2 - ECOSTUD - WALL INSULATIONS

TABLE 3 - ECOSTUD LOAD CAPACITIES - STUD HEIGHT WALLS

TABLE 4 - CONVENTIONAL WALLS - LOAD CAPACITIES

TABLE 5 - BEARING PRESSURE & LOADS PERPENDICULAR TO THE GRAIN

TABLE 6 - FRAMING - PLATE SYSTEMS

TABLE 1 ECOSTUD TYPES

ECOSTUD TYPE	MINOR STUD metric	MINOR STUD imperial	MAJOR STUD metric	MAJOR STUD imperial	SPACER SPACING
ECS-2:2	38x38mm	2x2	38x38mm	2x2	750mm
ECS-2:3	38x38mm	2x2	38x64mm	2x3	750mm
ECS-2:4	38x38mm	2x2	38x89mm	2x4	750mm
ECS-3:3	38x64mm	2x3	38x64mm	2x3	1200mm
ECS-3:4	38x64mm	2x3	38x89mm	2x4	1200mm
ECS-3:6	38x64mm	2x3	38x140mm	2x6	1200mm
ECS-4:4	38x89mm	2x4	38x89mm	2x4	

Spacers cut from 2x4 lumber,
Connector - trussplate 38x75mm or 25x100mm, all connections, both sides.

TABLE 2 - ECOSTUD - WALL INSULATION VALUE

WALL DEPTH METRIC mm	WALL DEPTH IMPERIAL inches	INSULATION VALUE BATTS	TOTAL BATTS RSI	TOTAL WALL RSI
190	7.5"	2-RSI 2.1	4.2	4.8
240	9.5"	1 RSI 4.9	4.9	5.4
290	11.5"	1 RSI 3.5+2.1	5.6	6.2
290	11.5"	2 RSI 3.5	7.0	7.6
350	14"	RSI 3.5+4.9	8.4	8.0
400	16"	2 RSI 2.1+4.9	9.1	9.7

TABLE 3

ECOSTUD LOAD CAPACITY PER STUD
STUD LENGTH = 2290mm
SPECIES GROUP S-P-F PAD- moisture content

ECOSTUD TYPE	LUMBER GRADE	IMPERIAL			METRIC		
		MAJOR STUD BEARING		BOTH BEARING	MAJOR STUD BEARING		BOTH BEARING
		SIZE "	Pj #	P #	SIZE mm	Pj kg	P kg
ECS-2:2	SS	2x2			38x38		
ECS-2:3	ET	2x3			38x64		
ECS-2:4	LR	2x4			38x89		
ECS-3:3	EU	2x3			38x64		
ECS-3:4	CC	2x4			38x89		
ECS-4:4	TT	2x4			38x89		
ECS-2:2	N	2x2			38x38		
ECS-2:3	O	2x3			38x64		
ECS-2:4		2x4			38x89		
ECS-3:3	#	**2x3**			**38x64**		
ECS-3:4	1	2x4			38x89		
ECS-4:4		2x4			38x89		
ECS-2:2	N	2x2			38x38		
ECS-2:3	O	2x3			38x64		
ECS-2:4		2x4			38x89		
ECS-3:3	#	**2x3**			**38x64**		
ECS-3:4	2	2x4			38x89		
ECS-4:4		2x4			38x89		

NOTES:
1- P = Pj + Pj(for minor stud)
P = total load carrying capacity of stud
Pj= load capacity of major stud
2- figures include load sharing factor of 10%.
3- Lateral bracing by adequate sheathing is assumed on major and minor stud.
4- All designs incorporating Ecostud are to be sealed by a structural engineer.
5- Spacers placed according to table 1.
6- Calculations based on the assumption that an Ecostud functions as a spaced column and are calculated according to CSA 086 section 3.4.2.3.

TABLE 4

CONVENTIONAL WALLS
STANDARD GRADE LUMBER
BEARING CAPACITY PER STUD

IMPERIAL				METRIC			
STUD SIZE	Fc'	AREA sq.in	P* lbs	STUD SIZE	Fc' Mpa	AREA mm	P* kg
2x2		2.25		38x38		1444	
2x3		3.75	814	38x64	1.36	2432	370
2x4		5.25	2200	38x89	2.64	3382	1000
2x6		8.25	5610	38x140	4.27	5320	2550

*includes load sharing factor of 1.1

$$P = \frac{1.1 \times Fc' \times A}{g}$$

NOTE: 2x2 wall not allowed by Building Code

TABLE 5

SPECIES GROUP S-P-F

BEARING CAPACITY OF WOOD PERPENDICULAR TO THE GRAIN

METRIC	IMPERIAL	WIDTH	LENGTH	AREA	Fc⊥ to grain	Pmax
mm	inches	mm	mm		Mpa	
38x38	2x2	38	38	1444	1.67	270
38x64	2x3	38	64	2432	1.67	450
38x89	2x4	38	89	3382	1.67	630
38x140	2x6	38	140	5320	1.67	1000
38x184	2x8	38	184	6992	1.67	1300
38x235	2x10	38	235	8930	1.67	1670
38x286	2x12	38	286	10868	1.67	2030

TABLE 6

PLATE LOCATION	PLATE SYSTEMS				
	PS #1 *	PS #2	PS #3 **	PS #4	PS #5
BOTTOM	ECOPLATE	ECOPLATE	ECOPLATE	12mm PLYWOOD	FULL DIMENSION LUMBER
FIRST TOP PLATE	FULL DIMENSION LUMBER	ECOPLATE 12mm PLYWOOD	ECOPLATE	12mm PLYWOOD 1x4	FULL DIMENSION LUMBER
# 2 TOP PLATE	2x4	2x4	2X4	2x4 2x4	2X4
TOTAL DEPTH OF PLATES	114mm (4.5")	126mm (5.0")	114mm (4.5")	119mm (4.7")	114mm (4.5")

* - See drawing 3
** - See drawing 4

NOTE: The Ecostud when it is used as a plate, is referred to as an Ecoplate.

APPENDIX AA-3

DRAWING 1 ISOMETRIC OF ECOSTUD ECS-2:3

DRAWING 2 ISOMETRIC OF ECOSTUD ECS-3:3

DRAWING 3 STANDARD ECOSTUD WALL SECTION

DRAWING 4 ECOSTUD - TYPICAL CROSS-SECTION DETAILS

ECOSTUD TYPE ECS-2:3

TRUSS PLATE CONNECTORS
ALL CONNECTIONS
BOTH SIDES

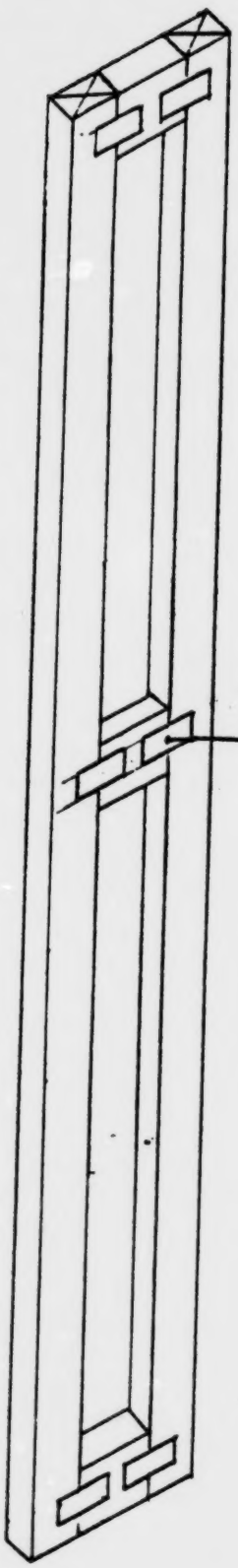
MAJOR-STUD
38x64 MM (2x3")

SPACER 38x89 MM (2x4")
TRUSS PLATE CONNECTORS

MINOR-STUD
38x38mm (2x2)

DRAWING # 1 page 36

ECOSTUD BUILDING SYSTEMS
8121 27 Avenue
Edmonton, Alberta
Canada, T6K 3C9
phone 461-2720



ECOSTUD TYPE ECS-3:3

TRUSS PLATE CONNECTORS
ALL CONNECTIONS
BOTH SIDES

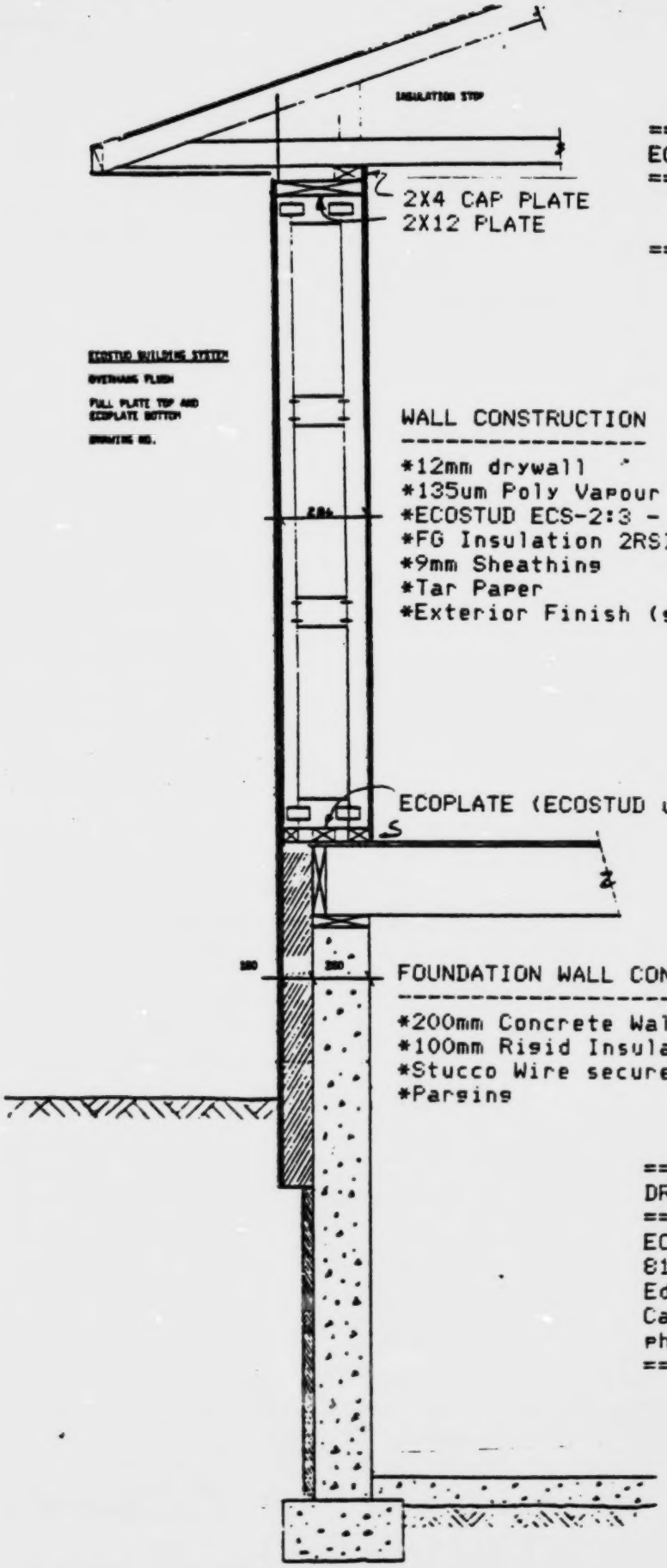
MAJOR-STUD = MINOR-STUD
38x64 MM (2x3")

SPACER 38x89 MM (2x4")

TRUSS PLATE CONNECTORS

DRAWING # 2 page 37

ECOSTUD BUILDING SYSTEMS
8121 27 Avenue
Edmonton, Alberta
Canada, T6K 3C9
Phone 461-2720

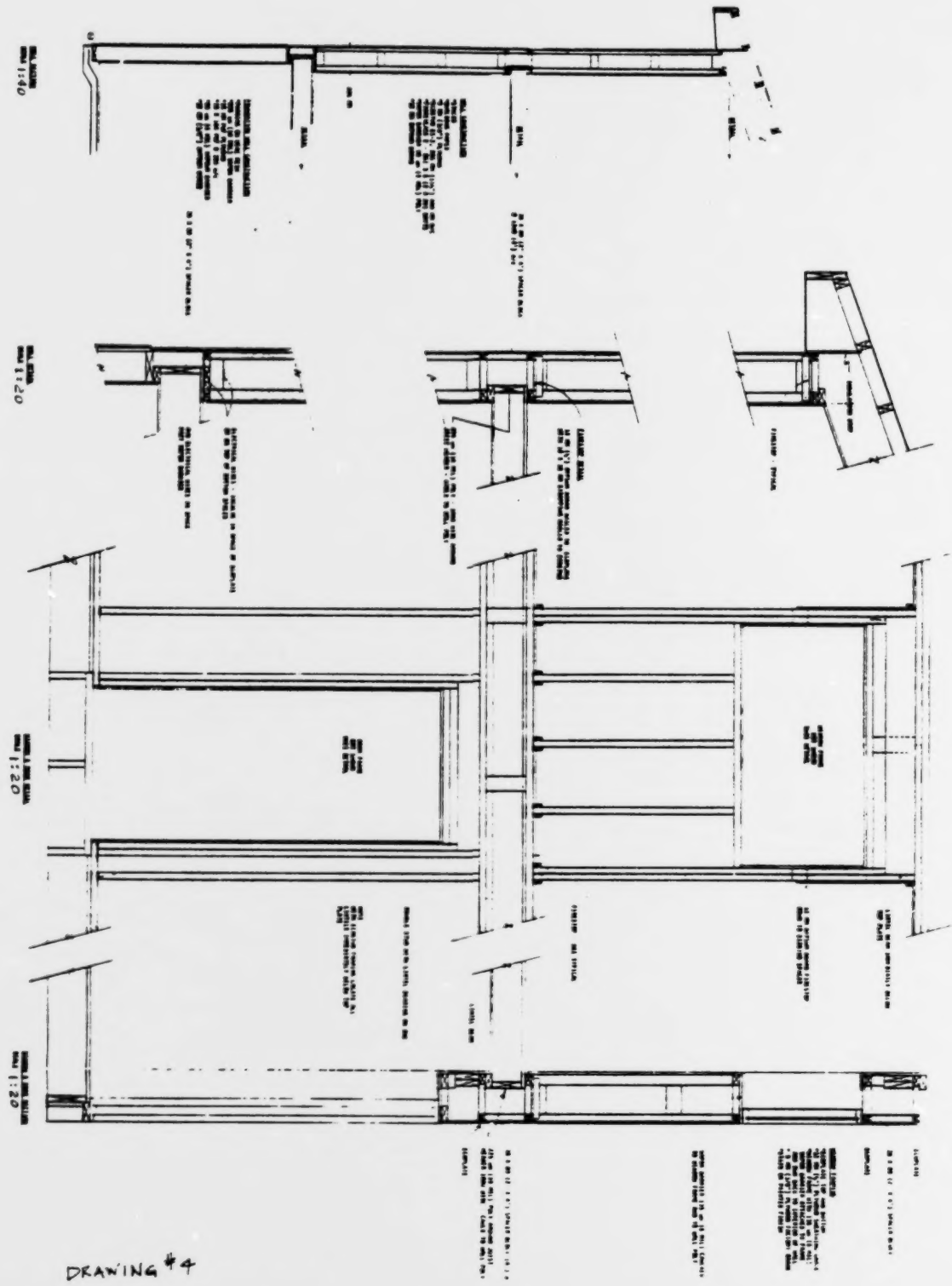


ECOSTUD TYPICAL SECTION

CANTILEVERED BEARING
FLUSH EXTERIOR

DRAWING # 3 page 38

ECOSTUD BUILDING SYSTEMS
8121 27 Avenue
Edmonton, Alberta
Canada, T6K 3C9
phone 461-2720



DRAWING #4

ECOSTUD WALL	
CROSS SECTIONS & DET.	
AS SHOWN	NOV 15 1982
	D. BEGIN
PAGE 39	

ECOSTUD BUILDING PRODUCTS
105 - 10235 124 STREET
EDMONTON, ALBERTA
PH. 488 - 7106

PART B

ECOSTUD DEMONSTRATION HOUSE

1.0 INTRODUCTION

Subsequent to the Conceptual Study on the Ecostud Building System, Jack and Joyce Tipping of Fort Assiniboine, desired to build an energy efficient home. The Ecostud system was recommended by the firm of G.M. Rekken and Associates as a system that would be more cost effective than the 2x6 + 2x3 strapping system the firm had already been involved with in a previous research house.

G. M. Rekken was the principal design consultant. Ecostud Building Products served as a supplier of preassembled Ecostuds.

1.1 SCOPE

This report briefly covers other energy conscious construction and appurtenances that were incorporated into the Demonstration House. Although some of the information does not relate directly to the Ecostud System, it is included as we are concerned with the effectiveness of the Ecostud as an integrated building system.

2.0 DESIGN

2.1 DESIGN - GENERAL

The house has a total finished floor area of 215 square metres (2,300sq.ft.) including the basement which is fully finished with a full 2.4m ceiling. The house is 11m x 8.5m (36x28') outside dimensions not including the attached garage. The walls are framed with the Ecostud ECS-2:3 which is formed from a 2x2 and a 2x3 and are 285mm in depth. The end walls are

non-bearing and were balloon framed and varied in height from 3.6 to 6.1m; (see Drawing #3 section E). The north wall which is two storeys is framed in the traditional way with the second floor stud wall bearing on the second floor; (see Drawing #3 section A).

Utilizing the Ecostud's ability to cantilever from the base plate, the joist header was recessed from the exterior wall. This recess allowed the vapour barrier to:

1- wrap around the joist header and

2- to have adequate insulation to prevent any condensation; (see Drawing #3 section A).

This system was used between the foundation and the first floor wall and between the first and second storey on the north wall; (see Photographs 4, 7 and 8).

The exterior walls are stucco except for the south wall. The full weight of the exterior wall is transferred to the interior bearing studs by the spacers and the connectors.

2.2 STRUCTURAL

The structural design analysis is outlined section 3 of part A. The south wall is 3700mm high. In some cases, the 2x3 of the Ecoplate is not of sufficient width to carry the vertical load. To achieve sufficient bearing area, 2x4 pieces were laid flat beneath the bottom spacer of the Ecostuds.

2.3 WIND and LATERAL BRACING

Lateral bracing is required on the interior major stud for it to develop the Ecostud's full potential as a column. The lateral bracing in a standard wall is provided by the exterior sheathing but with the Ecostud framing system, the lateral

bracing cannot be assumed to be fully transferred to the interior major stud and the drywall may not provide sufficient bracing. Therefore steel horizontal and diagonal strapping is required to enable the major stud to develop the full potential of the Ecostud as a column and to ensure lateral stability of the house.

2.4 DESIGN - OTHER FEATURES

Other energy conscious design features were also incorporated into the house: 1-All windows were triple glazed.

2-The heating for the house is supplied primarily by an air-tight wood stove located in the living room. A backup propane furnace located in the basement circulates the air continuously and provides heat when occupants are away for extended periods.

Note: Air convection and the circulated air system were inadequate to remove the hot air from the cathedral ceiling. This resulted in the stratification of the heated air on the second storey. The rotating fan, located in the ceiling, had to run at high speeds to circulate this heated air. In retrospect, the return duct for such a system should draw air from the top of the cathedral ceiling.

3-Hot water tank assist. A black painted preheat tank was located behind the clerestory window over the second floor hallway. Heat is gained directly from the sun through this south facing window; (see Drawing 3 section C and Drawing 8). This pre-heated water then serves as the hot water tank feed. In winter, a copper preheat coil is located behind the wood stove in the living room and circulates the water by differential gravity of hot and cold water to the elevated preheat tank.

4-Since the house is essentially air tight, an "air to air heat exchanger"(AAHE) tempers fresh air and exhausts the interior air. The AAHE is activated intermittently by a timer. Additional air exhaust switches in the kitchen and bathrooms increase fan speed on the AAHE, exhausing/-supplying additional air as required.

5-A pressure-treated wood foundation was selected as an economical foundation system which provides an insulated wall with RSI 4.8, (R27.5). This level of insulation is commensurate with the

levels of insulation in the remainder of the house.

6-The concrete floor and footing were poured monolithically also resulting in labour and material costs saving.

7-A green house is integrally attached to the south face of the house and has a half depth foundation.

8-A cathedral roof formed by 2x12 rafters at 600mm o/c with 2x4 purlins at 600mm o/c. This provides an insulation capacity of RSI 8.2 (R48) formed by RSI 2.1 in the purlins and RSI 3.5 + 2.1 in the rafters.

Note: There is no provision for an air space in the ceiling as sufficient precaution was taken to ensure a complete moisture seal. The vapour barrier was 135um (6mil) and poly hats were used on the electrical boxes.

9-All the plumbing that usually is placed below the floor joists was drilled through the joists to maintain full ceiling height in the basement.

3.0 CONSTRUCTION

3.1 ECOSTUD FABRICATION

The Ecostud and Ecoplate were preassembled off site. A 4.9m (16') jig was used for assembling all the lengths up to 6.1m. The trussplate were supplied by Truswal and were 38x75mm in size. They were carefully placed and applied using a sledge hammer having a 100mm diameter face. Even though this method is not the equal of a truss factory and is generally not recommended, the Truswal plates did prove to have an ability to draw the wood connection tight when they were pressed in place. The wood was all spruce and the 2x3 was mixed grades of Select Structural #1 & 2 with a moisture content, S-Dry. Trussplates were used for all connections and on both sides of the Ecostud.

3.2 FRAMING

The wood foundation wall was first erected; then the inset

floor joists were assembled and flooring placed. The joists had a bearing length on the plate of 89mm, the width of the 2x4 plate. The footings and floor were then poured as a monolithic slab of concrete. The stud length north wall and 3.6m south wall were framed and sheathed on the floor deck, then erected and braced inplace. The end walls which were up to 6.1 m in height were framed, sheathed and erected using wall jacks. The window and door frames were incorporated in the framing with 2x12 lumber or 19mm plywood; the plywood method proved to be more economical. The installation of the vapour barrier is described in section 3.6.

3.3 PLUMBING

A plumbing vent and stack from the upstairs bath was located in the exterior north Ecostud wall; (see Drawing 8). This section of plumbing was easily accomodated in the wall with adequate insulation to prevent freezing.

3.4 ELECTRICAL

The electrical wiring was easily accomodated in the Ecostud walls by simply running wire through the space in the studs. In addition, wiring between floors was facilitated by balloon framing of the non bearing walls and the inset joist system also allowed installation of wiring without drilling. At the inset joist, (see Drawing 3 section A & E), the wiring was run around the joist header and the only drilling required was of the foundation wall top plate. The same practice was followed between the first and second storey on the north wall. Poly hats were installed on all electrical boxes on the exterior walls.

3.5 INSULATION

Single batts of RSI 3.5 and a RSI 2.1 were placed together in the walls; this provided an insulation value of RSI 6.2 when the effect of the whole wall assembly is included. To fill the spaces in the Ecostud itself, a half width of RSI 2.1 was cut, then was peeled off in thirds and placed in the Ecostud cavity. This process, once initiated, was easily accomplished as the insulation was systematically placed in one direction.

3.6 VAPOUR BARRIER

A continuous vapour barrier, which is essential to all energy efficient construction, was incorporated into the building envelope. This feature was readily accomplished by laying a meter width of 225um (10mil) poly over the foundation walls before placing the floor joist. Upon completion of the floor deck it is simply brought up around and stapled to the floor deck. The same procedure was used for the second floor north wall; (see Photograph 4, 6, 7 and 8). In the balloon framed walls the 225um poly was placed between the floor joist and the Ecostud; (see Drawing 3, section E).

Upon completion of electrical, plumbing , etc. in the interior walls 135um (6mil) poly was placed on the walls. Both these poly sheets were caulked together to form an air tight seal. To maintain the integrity of the vapour barrier at electrical boxes, vapour hats were placed on the electrical box before fixing it to the stud. The vapour hats were of the rigid type and required caulking where the electrical cable pierced the pan. The pans were caulked around the opening and although the procedure is not required by the manufacturer it is recommended with these types of pans.

3.7 STRAPPING - LATERAL BRACING

Before the vapour barrier was placed, diagonal and horizontal steel strapping was placed on the interior walls to provide mutual support between the studs.

4.0 POST CONSTRUCTION APPRAISAL

4.1 SPACER SPACING

The use of only three spacers in the Ecostud ESC-2:3 at the top, middle and bottom was adequate to maximize the load bearing capacity of the Ecostud. But during sheathing of the exterior, the 2x2 was found to be very bouncy and made nailing cumbersome. Thus the maximum spacing of spacers for Ecostuds using 2x2's, should be 750mm (at the third points) and not the 1150mm spacing used in the Demonstration House.

4.2 ELECTRICAL

Running wire within the wall from box to box tends to make insulation installation difficult; (see Photograph 9). Insulation installation could be better facilitated if the wiring were placed in the Ecoplate base plate rather than be run in the walls. Also the wiring required in the wall can be fastened to the center of the spacers and kept in the center of the cavity rather than being nailed to the side of the Ecostud. This will enable a layer of batt insulation to be placed on either side of the wiring. The recommended method is shown in Drawing 4 in Appendix AA-2.

4.3 FIRESTOPS

The full plate firestop can be replaced with an Ecoplate and 12mm drywall applied between studs to reduce the cost of plates; (see Drawing 4).

The firestop in balloon framing at the mid floor level should be placed at the nearest spacer level. All firestops composed of gypsum board should be strapped on one side with 1x2 boards to make a firetight seal; (see Drawing 4). The plumbing and electrical should precede firestop installation. This sequence also enables the firestops to be placed at the same time as the dry wall. Any electrical holes through the firestop can be sealed with drywall plaster.

4.4 INSULATION

The 285 mm depth Ecostud had RSI 2.1 (R12) and RSI 3.5 (R20) batts. Without increasing the wall depth, 2 RSI 3.5 batts can be placed to give a typical wall a total value of RSI 7.5 (R43), if more insulation capacity is required.

By following the above suggestions, in the preceeding two sections, labour time for installation of insulation will be reduced.

The placing of half width batts of one third depth in the cavity of the Ecostud itself was simple and not time consuming.

4.5 VAPOUR BARRIER

Vapour barriers, to be effective, must not sustain any cuts or tears during construction. To minimize the possibility of tears and cuts, heavy gage (6 mil) poly was specifed on the drawings. This can be reduced to 135um (4 mil) but in no case should 2 mil poly be used for a vapour barrier. Thus 90um (4 mil) should be the minimum specified for walls, ceilings and for attaching to window frames; around joist headers 135um (6 mil) should be the minimum specified.

Between floors the inset joist header with electrical wires

run on the outside maintains the integrity of the vapour barrier between floors; (see Drawing 4). Thus a continuous vapour barrier with all penetrations sealed can be easily achieved with Ecostud framing.

5.0 SUMMARY

The Ecostud provided a fast and efficient method of incorporating more insulation into the wood frame wall. In addition, the Ecostuds were erected full height on three walls which substantially reduced labour costs. Electrical labour costs were reduced as well since very little drilling was required. A complete vapour barrier envelope was attained by utilizing the Ecostud's ability to overhang the floor joists and by other relatively simple details, such at the use of poly hats on electrical boxes. The spacing of the spacers at 1150mm o/c made nailing exterior sheathing difficult and the spacing should be reduced to 750mm for Ecostuds using 2x2 minor studs. An alternative is to use 2x3 minor studs with spacer spacings of 1150mm.

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APPENDIX BB-1

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APPENDIX BB-1 ECOSTUD DEMONSTRATION HOUSE PHOTOGRAPHS

PHOTO 1 ECOSTUD DEMONSTRATON HOUSE

PHOTO 2 ECOSTUD ECS-2:3 WALL

PHOTO 3 ECOSTUD ECS-2:3 WALLS

PHOTO 4 ECOSTUD WALL BEARING ON INSET FLOOR JOIST

PHOTO 5 JUNCTION INTERIOR AND EXTERIOR WALL

PHOTO 6 WOOD FOUNDATION WALL

PHOTO 7 WOOD FOUNDATION WALL WITH INSET FLOOR JOIST

PHOTO 8 FIRST FLOOR - STUD BEARING WALL - NORTH SIDE

PHOTO 9 SECOND FLOOR - BEARING WALL - NORTH SIDE

PHOTO 10 PICTURE WINDOW FRAMING DETAIL

PHOTO 11 EXTERIOR DOOR FRAMING

PHOTO 12 KITCHEN WINDOW

PHOTO 13 PLUMBING IN ECOSTUD WALL

ECOSTUD DEMONSTRATION HOUSE PHOTOGRAPHS

PHOTO # 1
ECOSTUD DEMONSTRATON HOUSE

OWNER: Mr & Mrs JACK AND JOYCE TIPPING

LOCATION: FORT ASSINIBOINE, ALBERTA
SW 1/4-18-62-6-W5
DURING CONSTRUCTION - LOOKING NORTHEAST

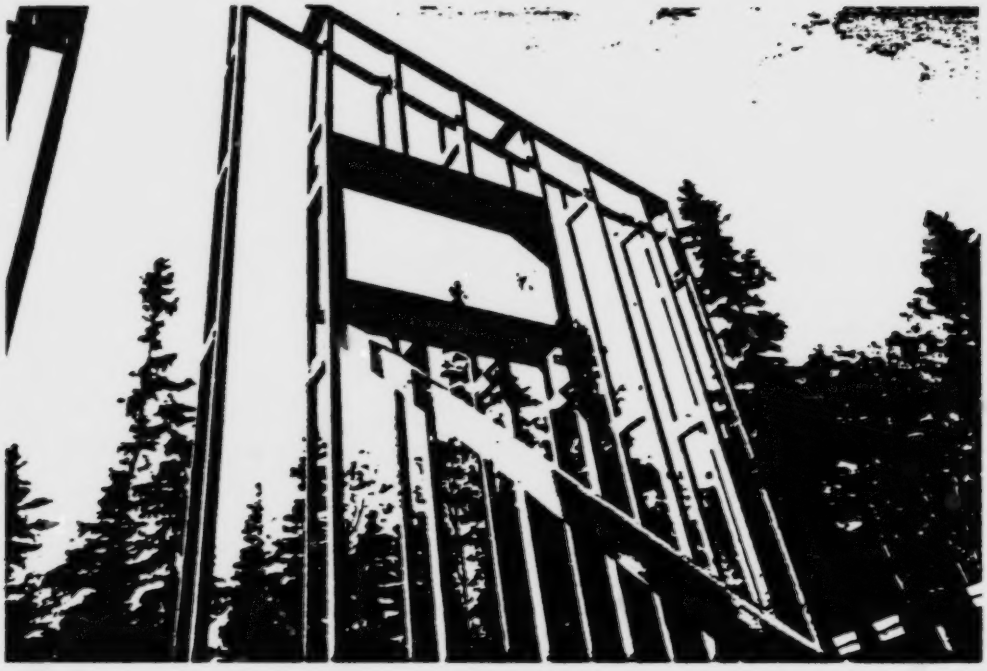


PHOTO # 2 ECOSTUD ECS-2:3 WALL
Note: No lintel beam or crippies on window since non-bearing wall.

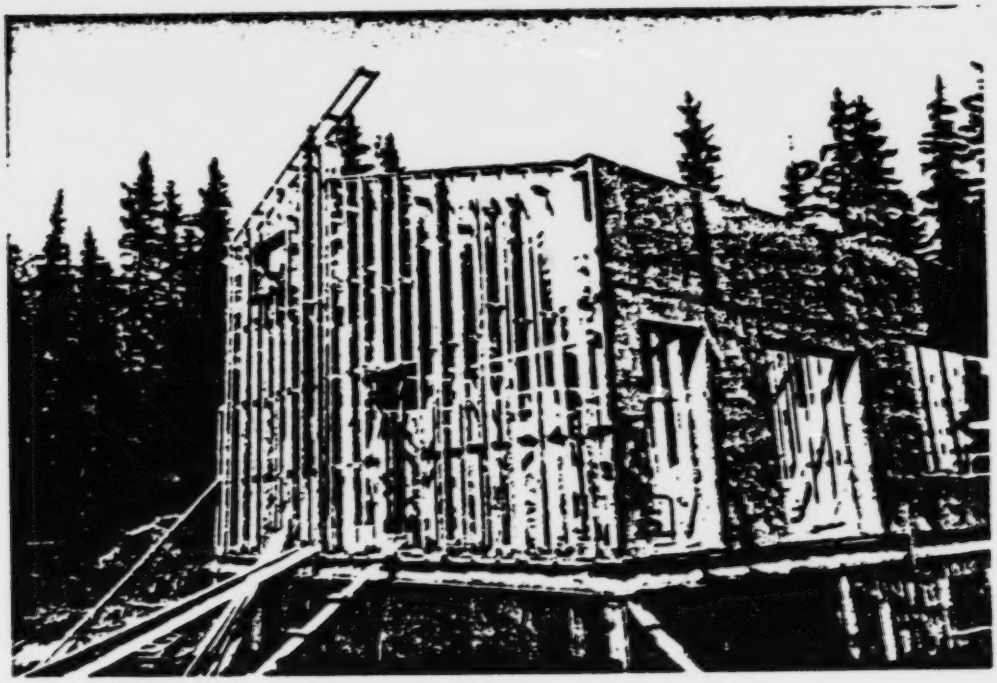


PHOTO # 3 ECOSTUD ECS-2:3 WALLS
Sheathed wall - 3.6 metres high - bearing wall - peak stud on end wall - 6.1 metres high

PHOTO # 4

ECOSTUD WALL BEARING ON INSET FLOOR JOIST

PHOTO # 5

JUNCTION INTERIOR AND EXTERIOR WALL
Insulaton and 135um (4mil) poly placed before interior partition, 2x12 framing and lintel for window.

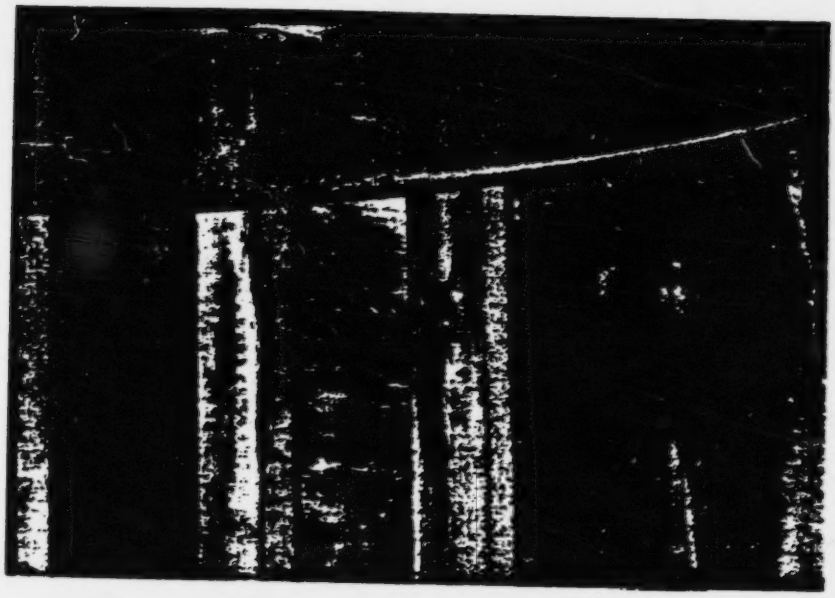


PHOTO # 6 WOOD FOUNDATION WALL
2x8's at 400mm o/c - Notice 10mil poly vapour barrier that goes around joist header, to enable a continuous vapour seal.

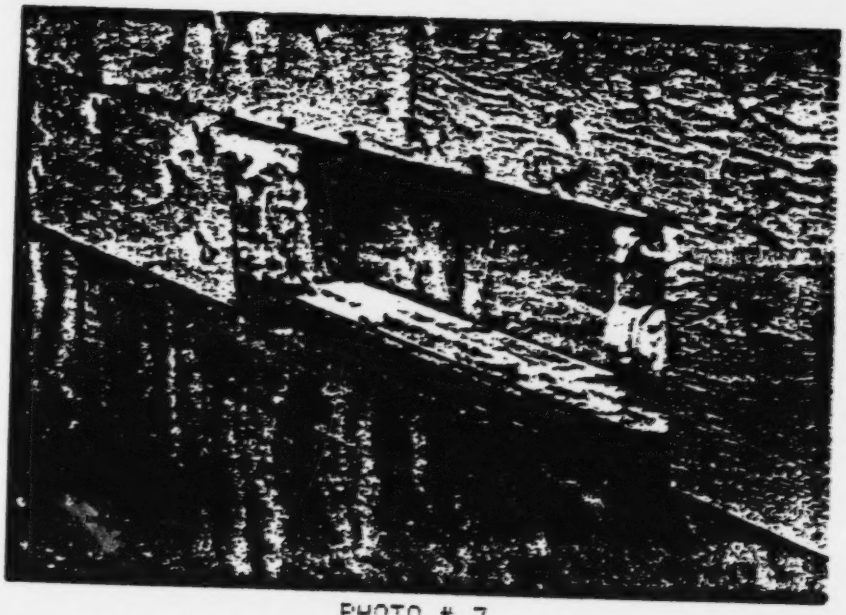


PHOTO # 7
WOOD FOUNDATION WALL WITH INSET FLOOR JOIST
Notice joist header covered by poly, then 140mm of fibreglass insulation; this gives a fully insulated vapour barrier between floors.

PHOTO # 8 FIRST FLOOR - STUD BEARING WALL - NORTH SIDE

286 mm depth Ecostud ECS-2:3 @ 400 mm o/c
Top plates: 2x4 on top of 2x12, the 2x12 serves as the firestop.
10 mil poly vapour barrier around joist header,
2x8 joists bearing on 2x4 top plate.

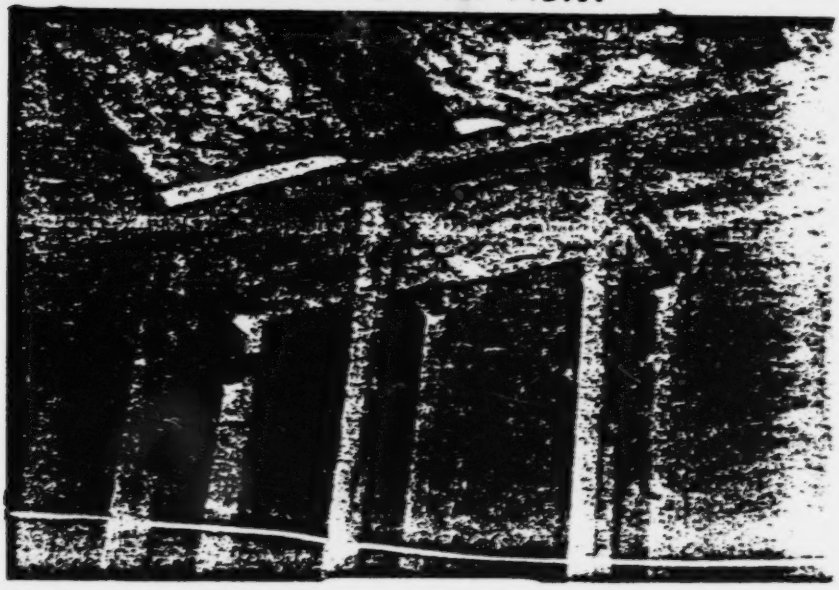


PHOTO # 9 SECOND FLOOR - BEARING WALL - NORTH SIDE

286 mm depth Ecostud ECS-2:3 @ 400 mm o/c,
2x12 first top plate for firestop,
2x4 second top plate,
2x12 rafter,
2x4 purlin, with RSI2.1(R12) fibreglass insulation.

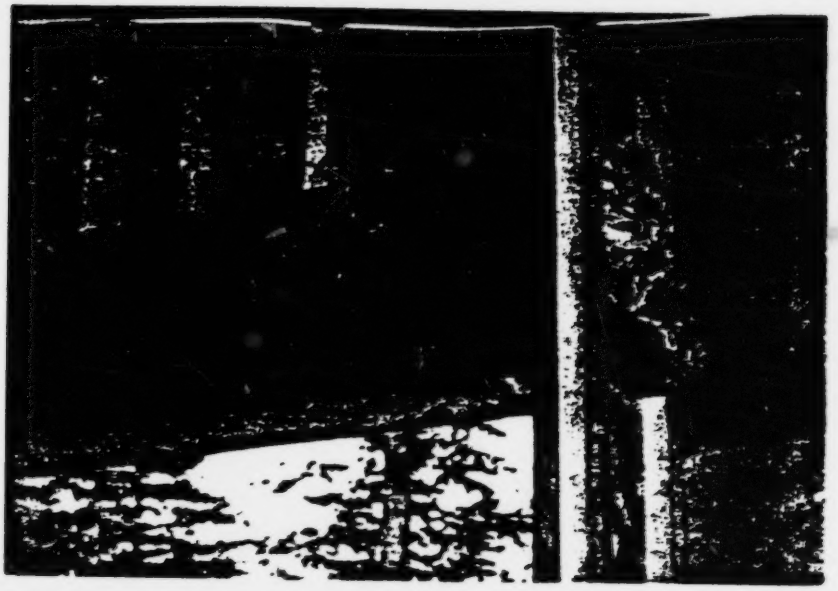


PHOTO # 10 PICTURE WINDOW FRAMING DETAIL
2 - 2x12's for lintel beam,
2x12 cripples.

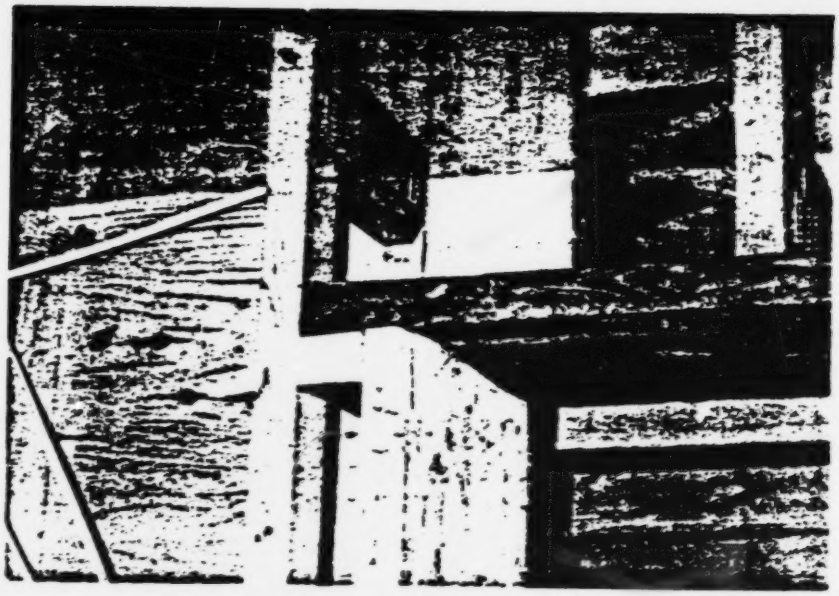
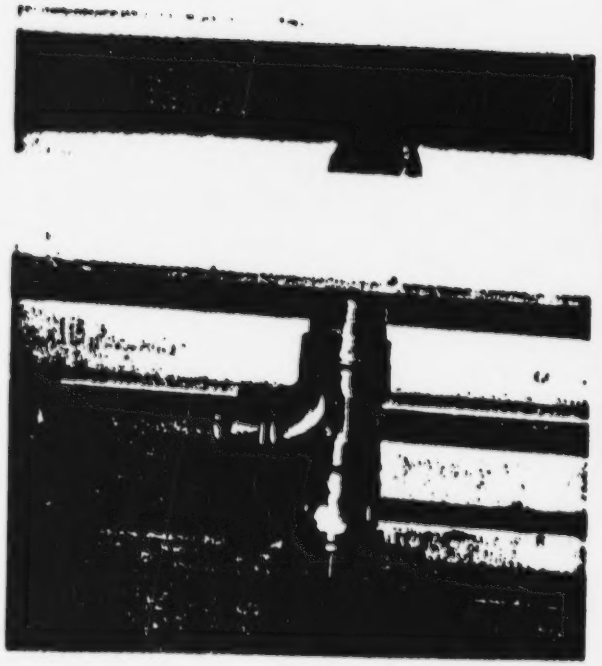


PHOTO # 11 EXTERIOR DOOR FRAMING
2x12 framing top and sides of door,
top plate cut to fit against nearest Ecostud.
NOTE: No lintel beam since non-bearing wall.



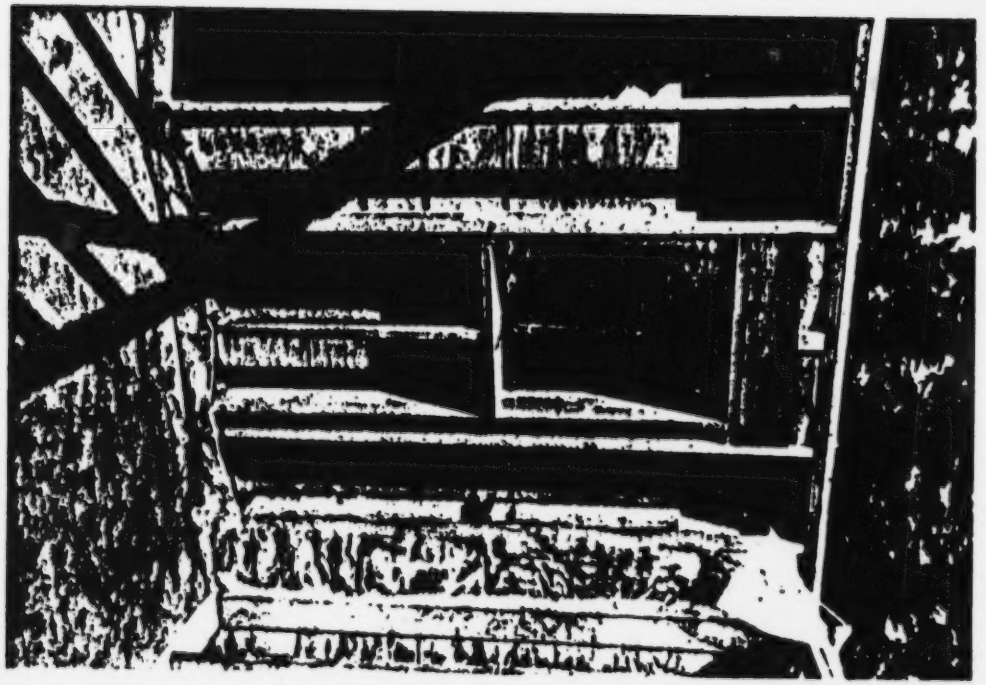


PHOTO # 12 KITCHEN WINDOW
2x12 lintel,
2x12 cripples,

PHOTO # 13
PLUMBING IN ECOSTUD WALL
located in Ecostud wall, directly below kitchen window shown in Photo # 12. Has adequate depth for insulation, to prevent freezing.

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APPENDIX BB-2

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APPENDIX BB-2 ECOSTUD DEMONSTRATION HOUSE - PLANS

1- SITE PLAN and FLOOR PLAN

2- CROSS SECTIONS and JOIST LAYOUT

3- WALL SECTION and DETAILS

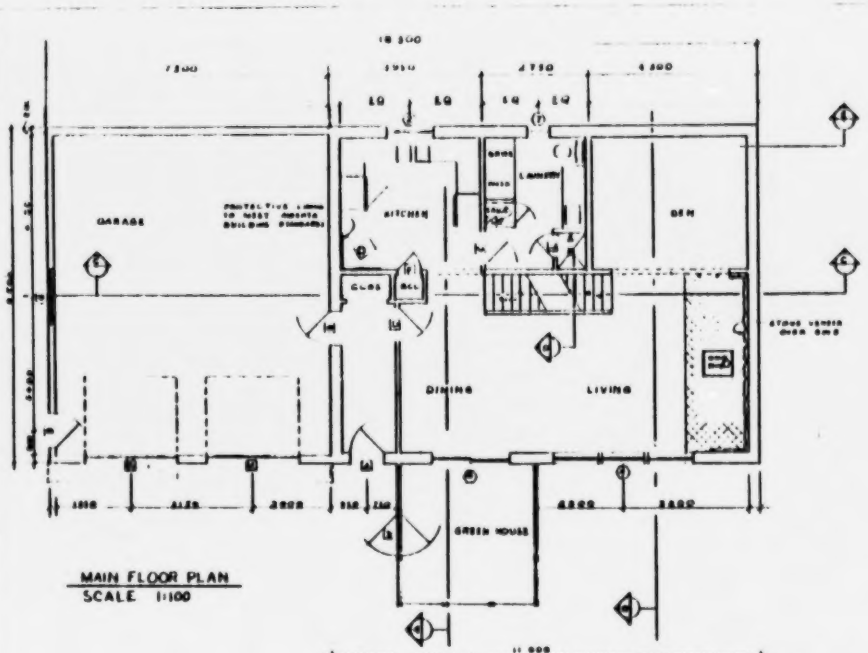
4- N/A (Green House Detail)

5- ELEVATIONS

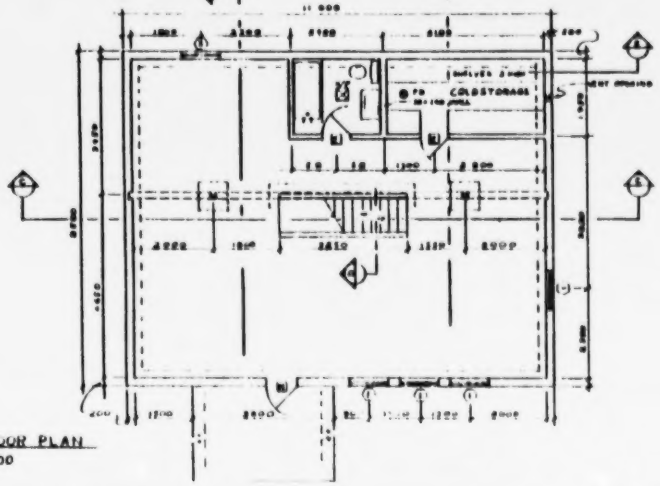
6- ECOSTUD - STUD LAYOUT

7- N/A (Electrical)

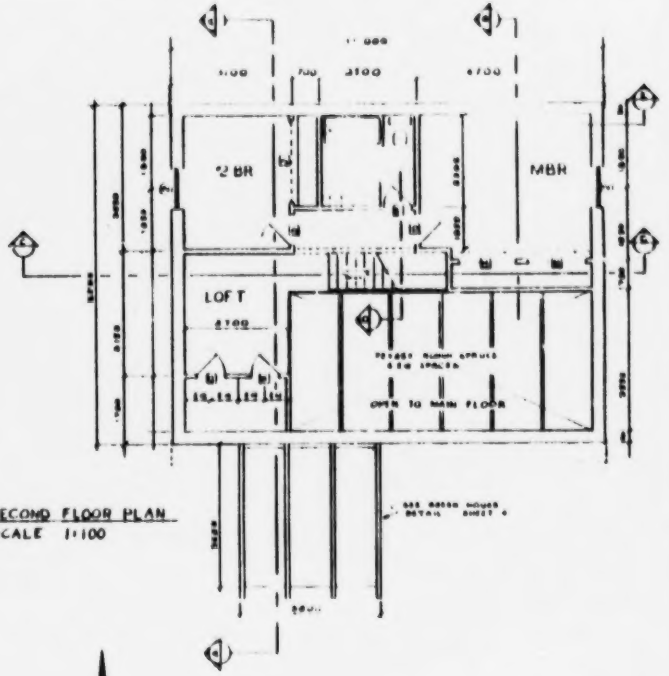
8- N/A (Plumbing and Mechanical)



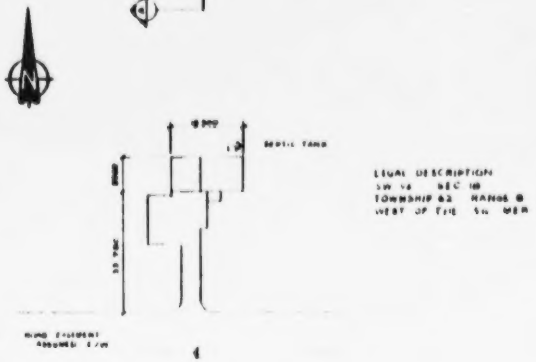
MAIN FLOOR PLAN
SCALE 1:100



BASEMENT FLOOR PLAN
SCALE 1:100



SECOND FLOOR PLAN
SCALE 1:100



SITE PLAN
SCALE 1:1000

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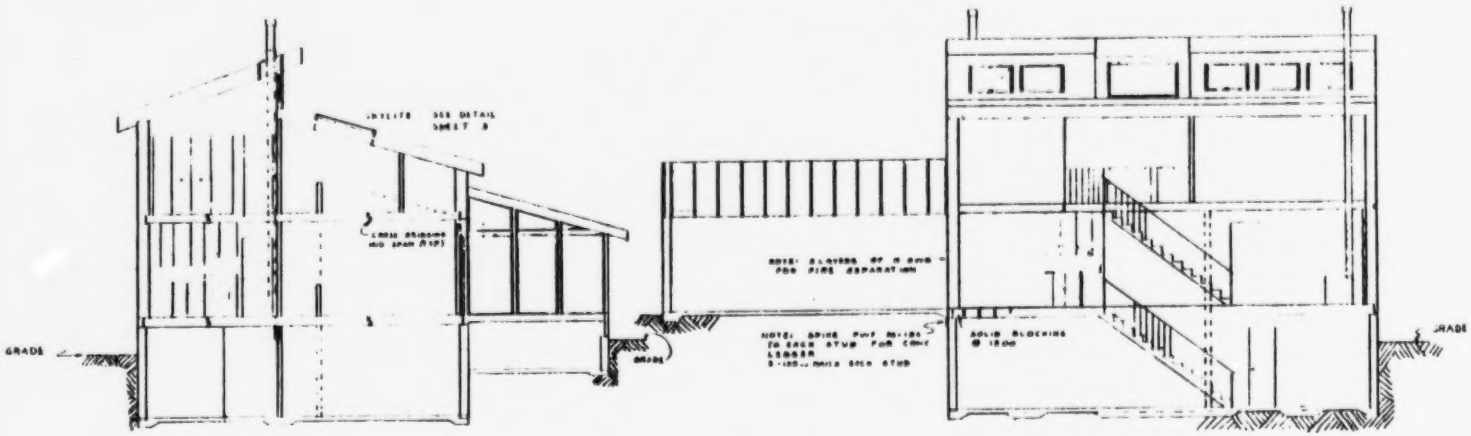
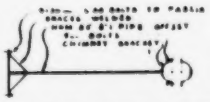
PAGE 39

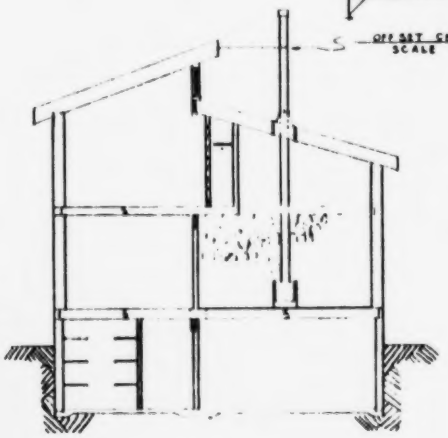


CROSS SECTION (A)
SCALE 1:100

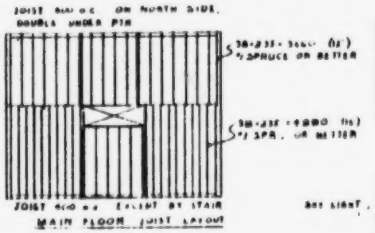
CROSS SECTION (C)
SCALE 1:100



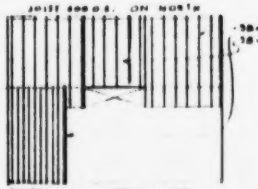
OFFSET CHIMNEY SUPPORT
SCALE 1:40



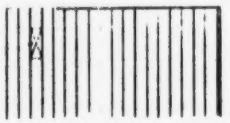
CROSS SECTION (B)
SCALE 1:100



MAIN FLOOR JOIST LAYOUT



NORTH ROOF RAFTERS



SOUTH ROOF RAFTERS

ROOF RAFTER LAYOUT
SCALE 1:100

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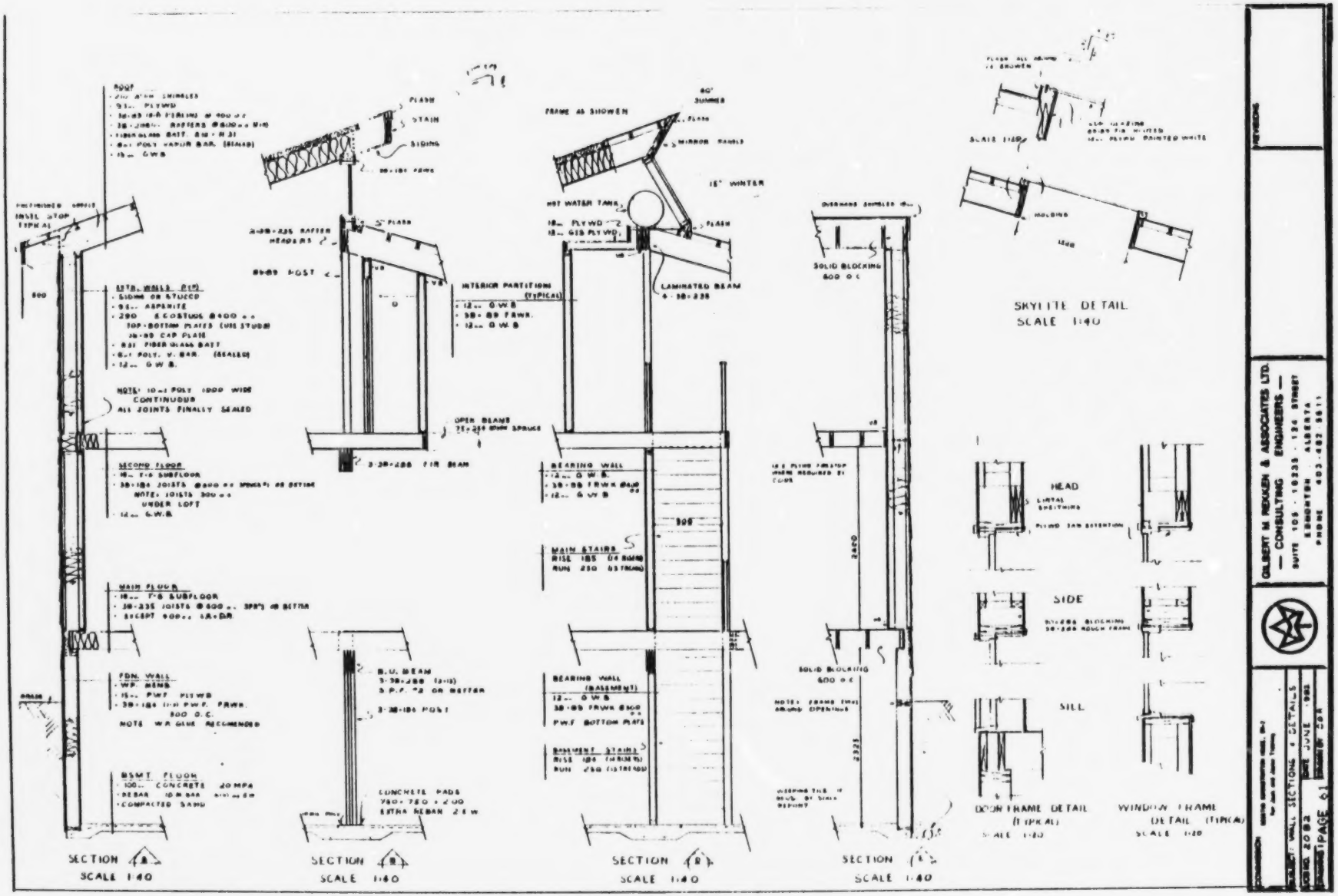
EDMONTON ALBERTA
PHONE 482-3611

CROSS SECTION & JOIST LAYOUT
DATE 20 82 JUNE 1982
PAGE 60


ROOF
EXTR. WALLS (1)
SECOND FLOOR
MAIN FLOOR
FDN. WALL
BSMT. FLOOR
SECTION A
SCALE 1:40
SECTION B
SCALE 1:40
SECTION C
SCALE 1:40
SECTION D
SCALE 1:40
SKYLITE DETAIL
SCALE 1:40
HEAD
SIDE
SILL
DOOR FRAME DETAIL
(TYPICAL)
WINDOW FRAME
DETAIL (TYPICAL)
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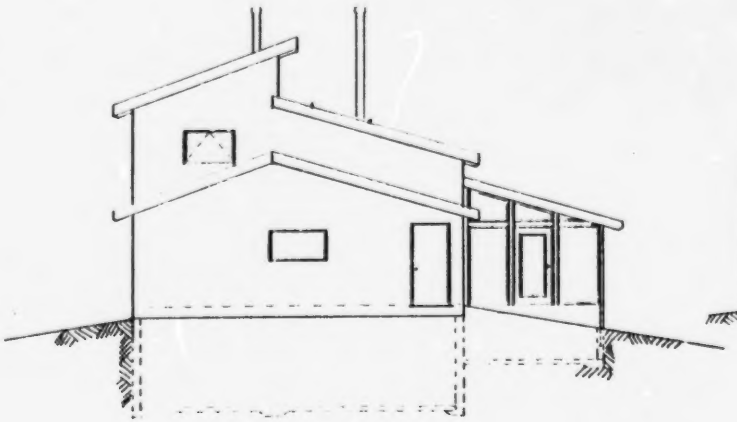
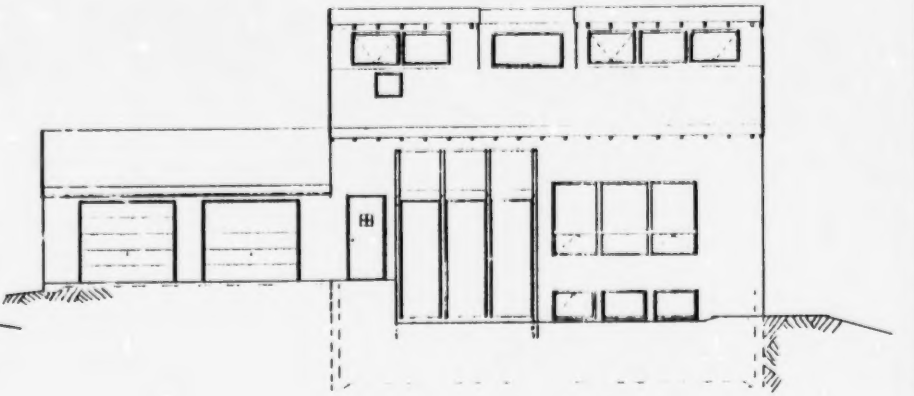
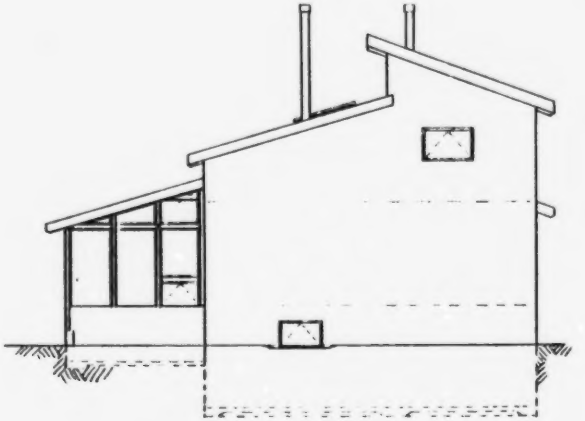
EDMONTON ALBERTA
PHONE 403-482 5611
WALL SECTIONS + DETAILS
JUNE 1983
PAGE A1



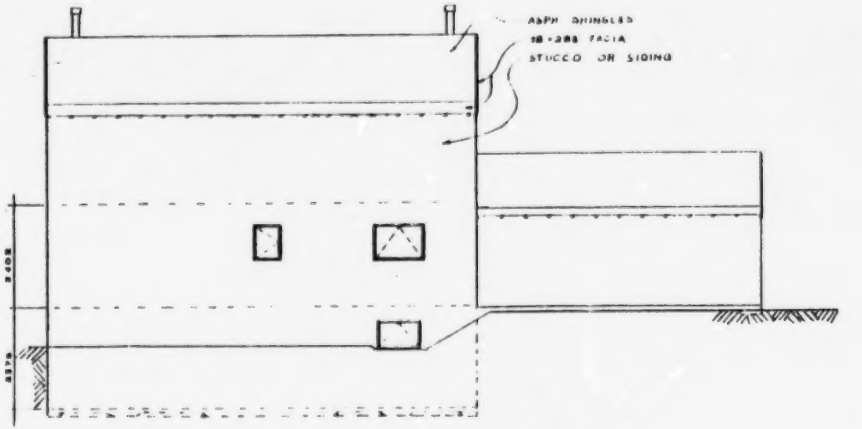
WEST ELEVATION
SCALE 1:100



SOUTH ELEVATION
SCALE 1:100



EAST ELEVATION
SCALE 1:100



NORTH ELEVATION
SCALE 1:100

REVISIONS

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SUBJECT ELEVATIONS
JOB NO. 2082 DATE JUNE 1982
DRAWING PAGE 62 DRAWN BY C.G.R.

ECOSTUD SCHEDULE

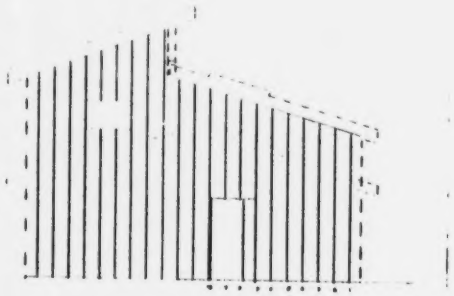
STUD	REQD	LENGTH
EAST AND WEST WALLS		
1	2	3191 mm
2	2	3741 "
3	2	3844
4	2	3988
5	2	4109
6	2	4252
7	2	6365
8 EAST	1	4478
8 WEST	1	2363
9 EAST	1	6600
9 WEST	1	2488
10	2	4723
11	2	5848
12	2	5988
13	2	6138
14	2	5932
15	2	5887
16 (MAY LOWER)	6	3750
16 UPPER	2	1060
17 UPPER	2	915
18	2	5410
19	2	5265
20	2	5118
21	2	4974

NORTH WALL		
22	22	2310
23	1	1140

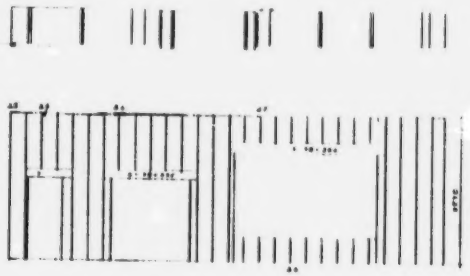
SOUTH WALL		
24	9	996
25	13	3870
26	7	1320
27	9	864

DOOR SCHEDULE

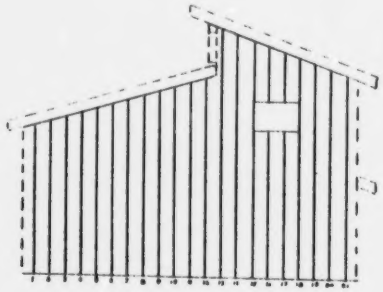
UNIT	DIM.	REQD	DISCRIPTION
A	910 × 2032	1	LOEWEN RH *287
B	910 × 2032	2	LOEWEN RHR *00
C	860 × 2032	2	HARDBOARD HOLLOW
D	760 × 2032	2	HARDBOARD HOLLOW
E	710 × 2032	5	" "
F	610 × 2032	1	" "
G	710 × 1800	2	" "
H	1800 × 2030	2	BIFOLD HOL CORE
J	2400 × 2030	1	" " "
K	2400 × 2000	2	GARAGE DOOR RH
L	600 × 1800	1	GLASS SHOWER
M	1000 × 2000	1	DBL DOOR GLAZED
N	810 × 1010	1	HARDBOARD



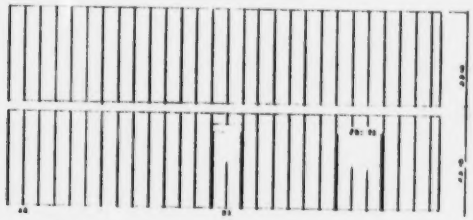
WEST ELEVATION STUD LAYOUT



SOUTH ELEVATION STUD LAYOUT
NTS



EAST ELEVATION STUD LAYOUT



NORTH ELEVATION STUD LAYOUT
NTS

WINDOW SCHEDULE

UNIT	NO.	REQD	LOCATION
1	AW 1008A	8	BSMT BEDROOMS/STORE
2	AW 1008A	3	BSMT KITCHEN
3	PB 1006	6	CLEAR STORY
4	PSKH/AW1068	5	L.R.
5	SL 1700	1	SOLAR DECK
6	SLI 1700 FIX	1	GARAGE
7	CA 0608BC	1	LAUNDRY
8	WP 1821 OP	1	DINING R. PATIO DOOR
9	SKY SLIDING	1	SKYLITE EXTRUDED PLASTIC

GREEN HOUSE WINDOW SCHEDULE

UNIT	TYPE	REQD	REMARKS	
10	SLIP [illegible]	3	EXTRUDED PLASTIC	DOOR FRONT SIDES
11	[illegible]	3	GLAZING GLAZED W/ FRAME	
12	[illegible]	6		
13	[illegible]	1		
14	AW 1008A	2	" FRAMED	

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REVISIONS

PROJECT ECOSTUD DETAILS
JOB NO. 2082 DATE JUNE 1982
DRAWING PAGE 65 DRAWN C.G.R.

ECOSTUD

PART C

COST AND BUILDING SECTION COMPARISONS

OF

LIGHT FRAMING SYSTEMS

FOR

ALBERTA DEPARTMENT OF HOUSING

INNOVATIVE HOUSING GRANTS PROGRAM

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REPORT BY

DAVID FERDINAND BEGIN, P. ENG.

JUNE 13, 1983

COST AND BUILDING SECTION COMPARISONS OF LIGHT FRAMING SYSTEMS

1.0 INTRODUCTION

In recent years, rising fuel costs have made it necessary to use higher levels of insulation in residential housing. A variety of ways have been developed which incorporate more insulation into the exterior wood frame wall.

It requires a high level of expertise, conscientious effort to be unbiased and much time to do a comparative cost analysis of alternate framing systems. Consequently the report has been prepared based on calculations prepared by two students from NAIT under the supervision of Mr. Gary Sorensen, an instructor at NAIT in the Building Construction Engineering Technology Department (BCET).

The labour cost calculations are based on multi-unit projects in excess of $250,000 and on average rates of production. The actual construction costs may vary significantly from those shown in this report but the results can be used to compare the various systems studied and to select a cost effective system.

The labour costs, especially for labour intensive systems such as Larsen and Double Stud, may show better than they should due to the difficulties in assessing this extra labour. In particular the labour cost for erection of the Larsen-Truss was raised 50% to $9.00 from $6.00 in the "Rekken-Neiman Report" in order to be comparable with the other labour costs used.

The material costs are from suppliers in the city of Edmonton. The cost of the Ecostud ECS-3:3 has been established

for commercial size job at $2.13/metre (0.65/foot).

The study compares nine different wood framing systems with the conventional 2x4 frame wall. The systems included are being used in the building industry today.

1.1 SCOPE

This report studies nine different wall systems and then makes comparisons in three ways:

1-a written comparison between the systems,

2-a direct cost comparison in dollars per lineal metre,

3-a cost insulation ratio comparison in dollars per metre per RSI and

4-the percentage cost and thermal resistance increases with respect to conventional 2x4 framing.

The cost breakdown includes both labour and materials separately and are for standard height walls without windows, doors, electrical etc. As well the exterior and interior finishes are the same for all wall systems. To ensure the Larsen-Truss and Double-Wall systems studuied were as cost-effective as possible, an exterior finish that did not require exterior sheathing was selected (to eliminate double sheathing); (see figure 6 and 7 in appendix). These above assumptions have been made to reduce the number of variables and to simplify cost estimation, especially labour. For the framing systems which incorporate rigid insulation to replace the exterior sheathing, the costs of installing diagonal steel strapping which may be required for lateral stability of the structure have not been included. It should be noted however that many of these systems have been constructed with redundacies such as double sheathing and in actual construc-

tion these systems may be more costly than indicated by this cost comparison study.

1.2 SUMMARY

Nine different systems of wood framing are studied and compared to one another on the basis of costs, labour, simplicity of construction. The systems are also compared according to equivalent thermal characteristics to delineate the better and/or more economical system.

2.0 WALL SYSTEM - DESCRIPTION AND ANALYSIS

2.1 CONVENTIONAL 2X4 WALL - See Figure 1

This is the standard wall that has been developed in the wood framing industry and is currently used in more than 90 percent of residential construction. An important design detail that can easily be incorporated in this wall as well as all the other wall systems is the use of the vapour box to seal the openings for electrical boxes. This enables a complete air-vapour seal of the wall which eliminates air transfer through electrical boxes, resulting in higher cost of heating infiltrated air.

The advantage of the 2x4 wall is that it is well known, accepted, easy to to construct, and has the lowest construction cost; but it provides only RSI 2.55 (R14.6). This amount of insulation is inadequate when considering the current and the rising price of heating and the relative ease of improving the exterior wall as shown in the following systems.

The disadvantages of the Conventional 2x4 Wall System are:

1-a low wall insulation value, RSI 2.55 (14.6) and

2-thermal bridging in the wood stud.

The Conventional Wall system is used as a basis to compare

the following wall systems.

2.2 CONVENTIONAL 2X4+50mm RIGID INSULATION - See Figure 2

The rigid insulation in this system can be either Glas-clad fiberglass or styrofoam-SM. This increases the wall insulation value to RSI 3.7 (R21). Since the rigid insulation cannot provide the rigidity to the wall of the replaced sheathing; steel diagonal strapping must be applied to either face of stud to provide wind bracing. The advantages of 2X4+50mm Rigid Insulation is that:

1-The extra costs of rigid insulation is partially offset by the removal of the plywood sheathing.

2-Thermal bridging of the wood stud is eliminated.

2.3 2X6 WALL @ 600mm O/C - See Figure 3

The 2x6 is framed in the traditional manner using 2x6 instead of 2x4 and the stud spacing is increased to 600mm from 400 to partially offset the increased cost of 2x6 studs. This wall has an insulation value of RSI 3.8 (R22).

The disadvantages to the 2X6 @ 600mm O/C system is that:

1-the 600mm spacing of studs is not totally accepted as being adequate support for 12mm drywall, and

2-Thermal bridging in the wood stud.

2.4 2X6 WALL @ 400mm O/C

This system uses the accepted 400mm o/c stud spacing.

The advantages are:

1-wall insulation is increased to RSI 3.9 (R22).

The disadvantages are:

1-the thermal bridging of the wood.

2.5 2X6 @ 400mm O/C + 50mm RIGID INSULATION

This system is similar to the 2X4 @ 400 + 50mm Rigid Insulation. The cost increases are minimized by eliminating the exterior plywood sheathing and providing rigid insulation in its place. To provide for the wind bracing previously supplied by the exterior sheathing, diagonal steel strapping is applied to either face of the stud wall. The advantages of this system are:

1-The insulation is significantly raised to RSI 5.1 (R29),

2-elimination of thermal bridging of the wood stud.

2.6 2X6 @ 600mm O/C + 2X3 HORIZONTAL STRAPPING - See Figure 4

In this wall system, the 2x6 @ 600mm o/c forms the basic wall with the exterior sheathing providing lateral stability. The poly vapour barrier is placed on the interior of the 2x6 framing. 2x3 are strapped on the narrow edge horizontally at 600mm o/c to the interior with 125mm spikes.

The electrical is installed in the space provided in the 2x3 without having to pass through the vapour barrier.

The advantages of this type of construction are:

1-the insulation value is increased to RSI 5.3 (R30);

2-the construction is relatively simple and all the added labour is within a closed-in structure;

3-the thermal wood bridge is eliminated;

4-the vapour barrier is recessed 64 mm which eliminates the extra labour of installing vapour pans at electrical boxes;

5-electrical installation costs may be marginally reduced since less drilling to install wiring is required.

The disadvantage of the 2X6+2X3 system is that:

the method is labour intensive, requiring more steps

in the construction process.

2.7 ECOSTUD ECS-3.3 - See Figure 5

The Ecostud is a preassembled product typically formed by two longitudinal members, two 2x3's separated by three wood spacers located at the top, bottom and midpoint; the whole assembly is fastened together with trussplates.

The Ecostud wall is framed in the traditional manner with Ecostuds and Ecoplates (an Ecostud used as a plate) replacing the conventional 2x4 studs and plates except that a 2x4 can be used for the second top plate. The stud space is filled with 2 RSI 3.5 (R20) batts which give the wall a total rating of RSI 7.4 (R42).

The advantages of the Ecostud system include:

1-only one simple wall is framed which follows conventional framing practice;

2-electrical installation labour is reduced, little or no drilling is required through studs or plates for electrical wires;

3-no significant heat transfer through wood stud, thermal bridging area in wood wall is reduced from 10% to 2 %;

4-continuous vapour barrier envelope can extend around joist headers due to the Ecostud bearing on interior member;

5-width of the Ecostud can be varied to meet demands in different projects;

6-can be used for balloon framing.

2.8 CONVENTIONAL 2X4+LARSEN-TRUSS - See Figure 6

The Larsen-Truss is a preassembled truss formed by two 2x2 longitudinal members separated by plywood spacers at 600mm o/c that fit into a dato cut in the 2x2 and are fastened in place by nails and glue.

The structural load bearing wall is formed with 2x4's in the traditional manner and sheathed except that the poly vapour barrier is placed on the exterior of the sheathed wall.

The Larsen-Truss is fastened to the exterior @ 600mm o/c spacing. The 210mm cavity is filled with RSI 4.9 (R28) fiberglass batt insulation. An exterior finish is usually chosen that does not require exterior sheathing so as to avoid the cost of providing a second sheathing.

The advantage of the system are:

1-a recessed vapour barrier except that the polyethylene is exposed to sun and wind, see note #1 under disadvantages below;

2-can be used for renovations and will provide both insulation and a new vapour barrier.

The disadvantages are:

1-The poly vapour barrier is exposed to sunlight for a undetermined time during construction. Once poly is exposed to sunlight, a deterioration process is set in motion that continues after it is covered.

2-In summer the poly vapour barrier is exposed to high winds. In winter lower temperatures make the poly brittle. Larsen-Truss do not recommend winter construction.

3-All extra work is outside of a closed in structure and requires scaffolding.

4-It is labour intensive, essentially requiring two walls to be formed.

5-The insulation is exposed to the rain and snow until exterior sheathing is applied.

The Larsen-Truss costs are expected to be higher than the results of the analysis show since the trusses have to extend to the soffits at gable ends and these extra costs were not included as the could not be easily incorporated into this study.

2.9 DOUBLE-STUD WALL - See Figure 7

The Double-Stud wall is essentially two 2x4 walls separated to sandwich additional insulation as well as incorporate insulation within both. The exterior is framed at 600 o/c, interior at 400 o/c.

Again due to the high cost of this wall exterior finishes should be selected that do not require the additional exterior sheathing.

The Double-Stud wall has the advantages of:

1-incorporating adequate insulation and

2-recessing the vapour barrier,

These advantages are by far outweighed by:

1-The system is labour intensive; it requires the framing of two walls in a cumbersome and awkward manner.

2-The walls, depending on the method of erection, are very heavy to lift into place for a framing crew.

3-An excess of wood materials is used whereas there are other more economical methods.

3.0 WALL SYSTEMS SUMMARY

3.1 GENERAL

3.1.1 2X4 and 2X6 RIGID INSULATION SYSTEMS

Two types of rigid insulation suitable for exterior sheathing are presently available, styrofoam board and Glas-clad and there is little significant price difference.

There are two drawbacks of styrofoam-SM board that make the selection of Glas-clad more attractive:

1-It tends to form a second vapour barrier that is within the frost zone. To prevent this condensation in the wall small holes must be made in the styrofoam to allow trapped air to dissipate to the exterior.

2-During a fire, styrofoam releases toxic fumes.

3.2 AIR VAPOUR BARRIER

The air vapour barrier although incorporated for many years into conventional housing must be sealed completely to prevent convective air transfer from the outside to the inside. These areas of convective air transfer (air leakage) are:

1-Joist headers, at the floor level;

2-at electrical box outlets;

3-at other openings required in the building - chimneys, plumbing vents, attic doors, windows, doors, electrical wires through top plates;

4-the chimney flue, dryer vent and fresh air intake to the furnace.

This convective air transfer can be reduced or eliminated in the specified areas by the following methods:

1-JOIST HEADERS: Incorporate a vapour barrier around the recessed joist header and place adequate insulation to the exterior of the vapour barrier to prevent moisture condensation.

2-ELECTRICAL OUTLETS: For electrical outlets in the exterior walls and the ceiling, poly hats should be placed around the electrical boxes when wiring is installed. Two types that use different methods of sealing are available on the market, a rigid box made of stiff plastic and a poly hat made of 18 mil polyethylene.

The other sources of air transfer are beyond the scope of this report and must be sealed in an appropriate manner to obtain an air-tight structure.

The strength of the vapour barrier is also of major importance. Traditionally 45um (2mil) poly has been used but it tears easily and should not be used anywhere for vapour seal purposes. The minimum recommended for walls should be 90um (4mil); around joist headers, 135um (6mil). For this report 135um

(6mil) has been used in the cost calculations.

Three systems have the advantage of having recessed vapour barriers, the Larsen-Truss, Double-Stud, 2X6+2X3 Strapping. In these the electrical wiring is run to the interior of the vapour barrier, and no seals around the electrical boxes are required. Also, the vapour barrier being recessed is less subject to accidental puncture.

4.0 RESULTS

The individual costs are summarised in Table 1 and are ranked in ascending order of total costs. Table 2 shows:

1-column 3, cost per unit insulation,

2-column 4, cost increase with respect to conventional,

3-column 5, thermal increase with respect to conventional.

The last three systems have unit costs in the order of $14.00 per lineal metre of wall per RSI with Ecostud having the lowest unit cost.

Thermal increases of 50% can be incorporated in the modified conventional wood wall with an increase in wall costs in the order of 10% for three of the systems; (see first three systems in Table 2).

The 2X6+50mm Rigid and 2X6+2X3 both double the insulation value, with corresponding costs increases of 14% & 22%.

The Ecostud and 2X4+Larsen-Truss both triple the insulation with corresponding costs increases of 27% & 39%.

The results are graphed, Plate 1 shows thermal resistance increase versus cost increase. Plate 2 shows cost of wall per metre versus thermal resistance.

5.0 WALL SYSTEMS - EVALUATION

These wall systems incorporate in various ways additional insulation. Some use basically simple methods while others are labour and material intensive. These systems are grouped according to thermal characteristics and are evaluated with respect to one another to determine the better and more efficient ones.

5.1 2X6 @ 400 & 600mm O/C

The 600mm o/c is not an accepted spacing for drywall support, the costs increase for 400mm spacing is marginal, from 6% to 9%. Thus the 2X6 @ 400mm O/C would be the better selection.

5.2 2X4+50mm RIGID VERSUS 2X6 @ 400 O/C

The thermal characteristics are essentially the same RSI 3.76 (21.5) and 3.94 (22.5); while the cost increases are 6% and 9% respectively.

The 2X4+50mm Rigid has the advantage of covering the joist header with insulation, the 2x6 can also be made to overhang the joist header 50mm where rigid insulation can also be placed.

5.3 2X6+50mm RIGID VERSUS 2X3 HORIZONTAL STRAPPING

The thermal resistance increases are essentially the same RSI 2.02 and RSI 2.09 but the cost increases are 12% and 20% respectively. The advantage of the recessed vapour barrier must be weighed against an additional 8% cost for this benefit.

5.4 ECOSTUD VERSUS 2X4+LARSEN-TRUSS

The thermal resistance increases are identical at 2.92 but have cost increases of 34% and 41% respectively. The advantage of the recessed vapour barrier in the Larsen-Truss should be considered against the risks of exposing it to both sun and wind. The Larsen-Truss also is substantially more labour intensive and all extra labour is outside of a closed-in structure. The 2X6+2X3 Horizontal Strapping would be a more viable option to recessing the vapour barrier. The Ecostud is simple in construction and has a substantially lower cost increase.

5.5 DOUBLE WALL

The Double Wall although effectively increasing insulation can not be considered a viable option with the other simpler systems available.

5.6 RECESSED VAPOUR BARRIER VERSUS POLY HATS

The recessed vapour barrier is an attractive feature to incorporate in the deep wall systems as the electrical installation does not go through it. The 2X6+2X3 strapping system incorporates this recessed vapour barrier the most economical way. But it must be remembered that the ceiling will require the use of poly hats to obtain a vapour seal. With this factor, the extra cost of these systems to obtain the recessed vapour barrier feature does not warrant their use except if they are cost competitive. If the electrician must use poly hats on the ceiling, there is only a marginal increase in his costs to incorporate them on the wall as well.

The Larsen-Truss vapour barrier should be of the black poly which is not subject to ultra-violet light decomposition.

6.0 SUMMARY AND CONCLUSIONS

The conventional 2X4 system can be modified with a marginal cost increase, to raise the level of insulation significantly. The cost increase for four of the modified systems is less than 15% but increases wall insulation from 50% to 100%.

The Ecostud, for a 34% cost increase, triples the insulation level.

COST AND BUILDING SECTION COMPARISONS

OF

LIGHT FRAMING SYSTEMS

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APPENDIX CC-1

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APPENDIX CC-1

TABLE 1 COST SUMMARY

TABLE 2 COST AND THERMAL RESISTANCE COMPARISONS

PLATE 1 THERMAL RESISTANCE VERSUS COST

PLATE 2 COST OF WALL PER METRE VERSUS THERMAL RESISTANCE

TABLE 1 - COST SUMMARY

	EXT'R FINISH		FRAMING		INT'R FINISH		TOTAL COST		TOTAL WALL COST
	MAT'L	LABOUR	MAT'L	LABOUR	MAT'L	LABOUR	MAT'L	LABOUR	
1. 2x4 CONVENTIONAL WALL	18.08	11.63	16.40	16.16	3.67	12.92	38.15	40.71	78.86
2. 2x4 + 50mm RIGID INSULATION	18.08	11.63	19.81	17.71	3.67	12.92	41.56	42.26	83.82
3a. 2x6 WALL @ 600mm o/c	18.08	11.63	21.80	15.33	3.67	12.92	43.55	39.88	83.43
3b. 2x6 WALL @ 400mm o/c	18.08	11.63	23.70	16.15	3.67	12.92	45.45	40.70	86.15
3c. 2x6 WALL @ 400mm + 50mm RIGID	18.08	11.63	25.23	16.89	3.67	12.92	46.98	41.44	88.42
4. 2x6 + 2x3 HORIZONTAL STRAPPING	18.08	11.63	27.33	21.27	3.67	12.92	49.08	45.82	94.90
5. ECOSTUD ESC-3:3	18.08	11.63	39.74	19.34	3.67	12.92	61.49	43.89	105.38
6. 2x4 + LARSEN-TRUSS	18.08	11.63	35.64	29.63	3.67	12.92	57.39	54.18	111.57
7. DOUBLE STUD	18.08	11.63	35.99	32.01	3.67	12.92	57.74	56.56	114.30

NOTE:
1- All costs are in $/lineal metre of standard height wall, not including windows and doors, etc.

2- Labour costs are based on multi-unit construction and thus can be used only to compare systems relative to one another.

TABLE 2 COST AND THERMAL RESISTANCE COMPARISONS

	T COST OF WALL $/m	THERMAL RESISTANCE RSI	COST FACTOR $/m RSI	COST INCREASE FACTOR	THERMAL RESISTANCE FACTOR
1. 2x4 CONVENTIONAL WALL	78.86	2.55	30.93	1.00	1.00
2. 2x4 + 50mm RIGID INSULATION	83.82	3.76	22.29	1.06	1.47
3a. 2x6 WALL @ 600mm o/c	83.43	3.94	21.18	1.06	1.55
3b. 2x6 WALL @ 400mm o/c	86.15	3.94	21.87	1.09	1.55
3c. 2x6 WALL @ 400mm + 50mm RIGID	88.42	5.15	17.17	1.12	2.02
4. 2x6 + 2x3 HORIZONTAL STRAPPING	94.90	5.34	17.77	1.20	2.09
5. ECOSTUD ESC-3:3	105.38	7.44	14.16	1.34	2.92
6. 2x4 + LARSEN-TRUSS	111.57	7.45	14.98	1.41	2.92
7. DOUBLE STUD	114.30	8.16	14.01	1.45	3.20

NOTE:
1- All costs are in $/lineal metre of standard height wall, not including windows and doors, etc.

2- Labour costs are based on multi-unit construction and thus can be used only to compare systems relative to one another.

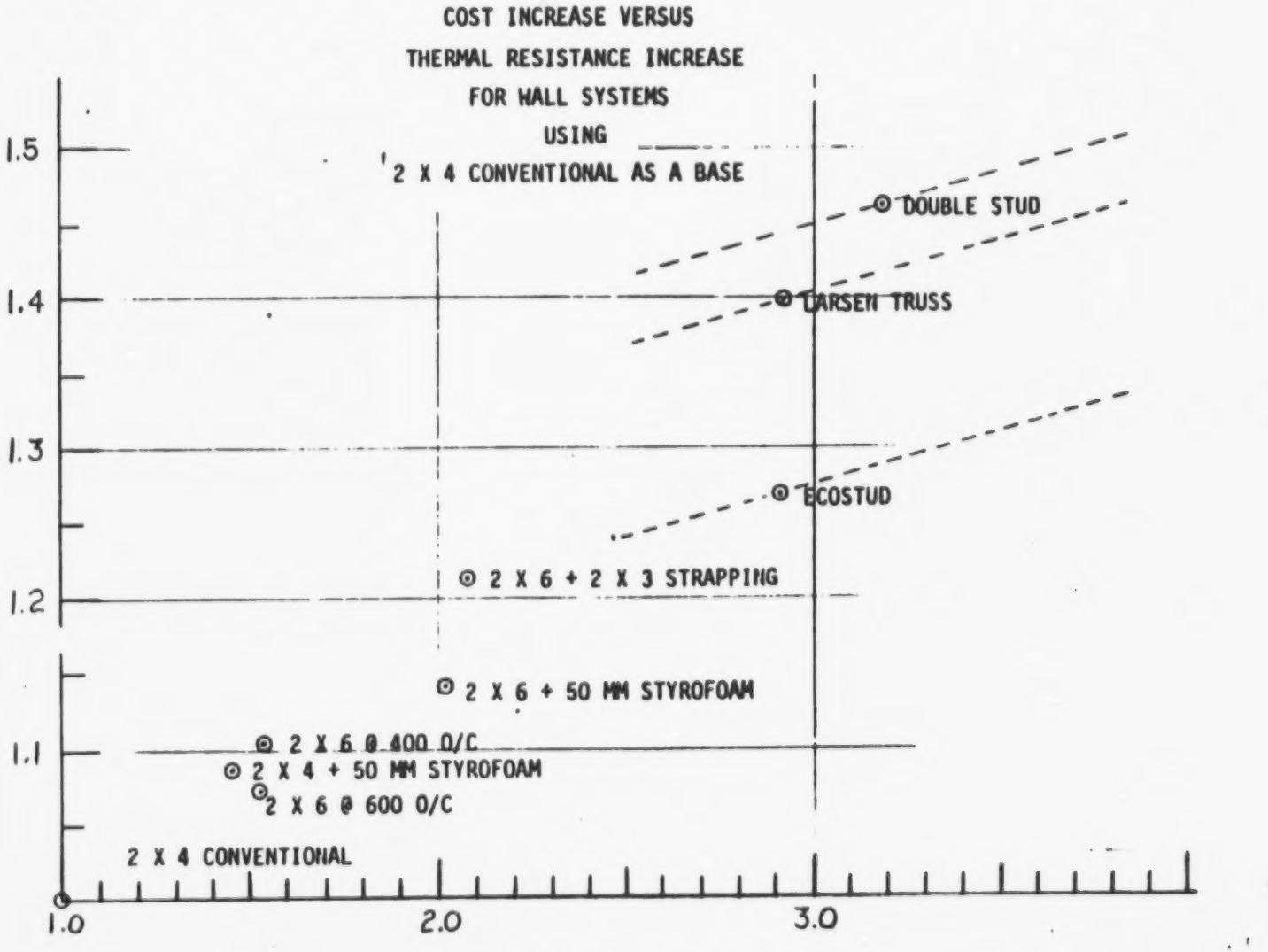
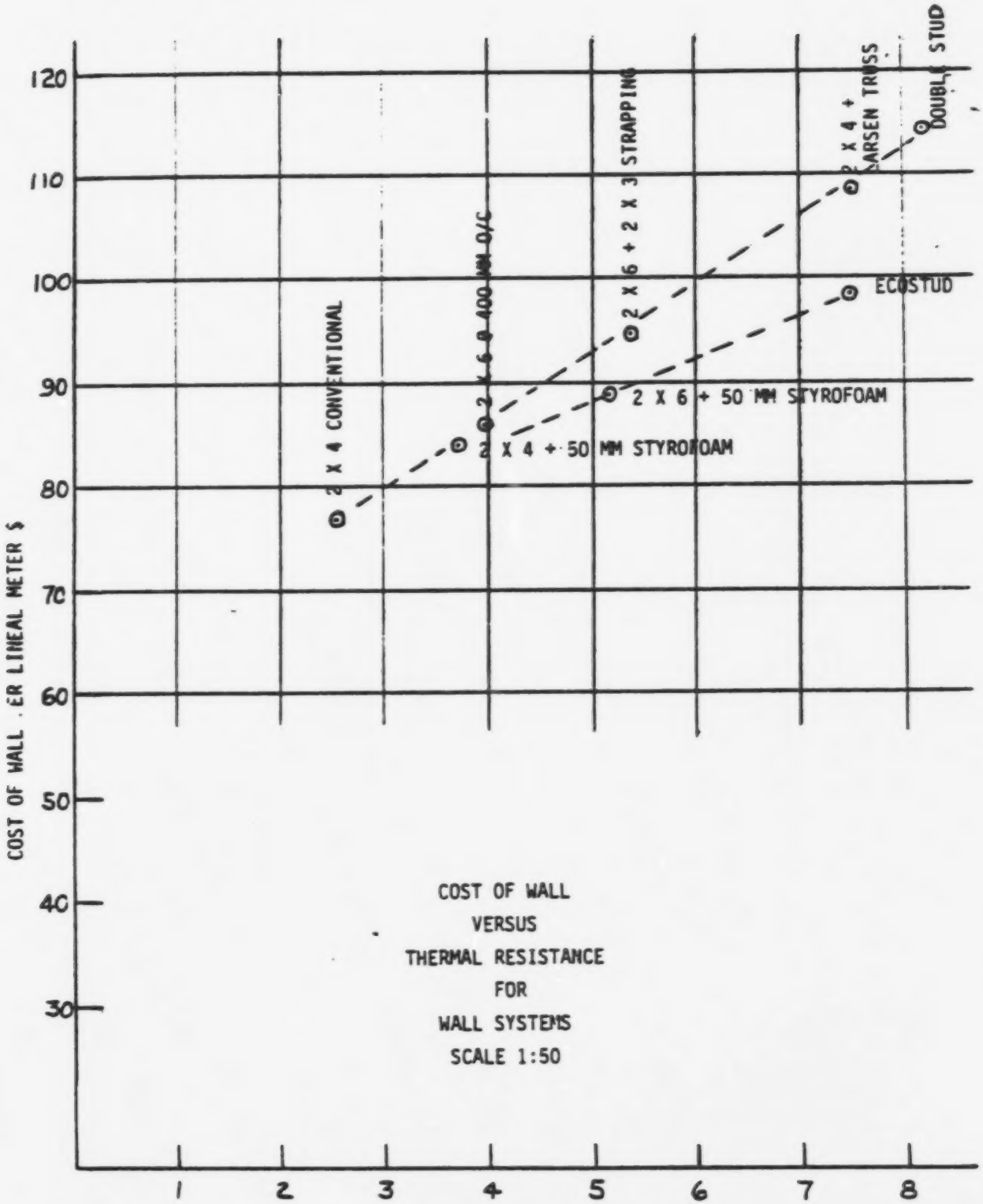

COST INCREASE VERSUS
THERMAL RESISTANCE INCREASE
FOR WALL SYSTEMS
USING
2 X 4 CONVENTIONAL AS A BASE
COST INCREASE
1.5
1.4
1.3
1.2
1.1
DOUBLE STUD
LARSEN TRUSS
ECOSTUD
2 X 6 + 2 X 3 STRAPPING
2 X 6 + 50 MM STYROFOAM
2 X 6 @ 400 O/C
2 X 4 + 50 MM STYROFOAM
2 X 6 @ 600 O/C
2 X 4 CONVENTIONAL
1.0
2.0
3.0
THERMAL RESISTANCE INCREASE

PLATE #1



COST OF WALL
VERSUS
THERMAL RESISTANCE
FOR
WALL SYSTEMS
SCALE 1:50

PLATE II

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APPENDIX CC-2

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COST CALCULATIONS

of

LIGHT FRAMING SYSTEMS

REPORT

by

CLAUDE REKKEN

JOHN NEIMAN

November 12, 1982

AMENDED

by

DAVID F. BEGIN, P. ENG.

June 1, 1983

REKKEN-NEIMAN

COST COMPARISON OF LIGHT FRAMING SYSTEMS

AMENDED DAVID F. BEGIN

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Material Cost Calculations

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DIAGRAMS WITH INSULATION CALCULATIONS

CONVENTIONAL 2X4 (38X89) Figure 1

CONVENTIONAL 2X4+50mm RIGID INSULATION Figure 2

2X6 (38x140) Figure 3

2X6+2X3 Horizontal Strapping Figure 4

ECOSTUD Figure 5

2X4+LARSEN-TRUSS Figure 6

DOUBLE STUD WALL Figure 7

++++ MATERIALS UNIT PRICES. ++++

The following is a list of the prices used in this study. These prices are contractor's rates as of November 1982, for the Edmonton area.

MATERIALS	UNIT COSTS
2x4 stud	1.35 /stud
2x6 stud	2.22 /stud
2x3 lumber	0.126 /foot
2x4 lumber	0.146 /foot
2x6 lumber	0.238 /foot
9mm plywood	7.65 /sheet
ECOSTUD ESC-3:3	0.65 /foot
LARSEN TRUSS	0.55 /foot
cedar siding	0.006 /bd. ft
12mm drywall	4.40 /sheet
INSULATION 15"	
RSI 1.4 (R8)	17.55 /bag
RSI 2.1 (R12)	15.78 /bag
RSI 3.5 (R20)	14.78 /bag
RSI 4.9 (R28)	/bag
RSI 7.0 (R40)	/bag
INSULATION 23"	
RSI 1.4 (R8)	28.76 /bag
RSI 2.1 (R12)	29.39 /bag
RSI 3.5 (R20)	22.88 /bag
RSI 4.9 (R28)	26.51 /bag
RSI 7.0 (R40)	/bag
styrofoam 50mm	11.75 /2x9 sheet
styrofoam 75mm	/2x8 sheet
glassclad 50mm	

++++ LABOUR UNIT PRICES ++++

All prices are based on union rates (North American Avreage) with avreage observed productivity.

Source: MEANS COST DATA

	UNIT COSTS		UNIT WALL COSTS PER LINEAL METER
2x4 framing 400mm o/c	2.65	/lineal ft	8.69 /lin. m
2x4 framing 600mm o/c	2.23	/lineal ft	7.31 /lin. m
2x6 framing 400mm o/c	2.23	/lineal ft	7.31 /lin. m
2x6 framing 600mm o/c	2.65	/lineal ft	8.69 /lin. m
plywood sheathing	0.21	/sq. ft.	5.51 /lin. m
horizontal strapping	0.22	/lineal ft	3.61 /lin. m
Application of insulation	0.10	/sq. ft.	2.62 /lin. m
Application of poly	3.30	/100sq.ft.	0.70 /lin. m

++++ LABOUR COSTS ++++

	ITEMISED	TOTAL
1-2X4 Conventional wall		
2x4 framing	8.40	
sheathing	5.43	
insulating	2.33	16.16
2- 2X4+50mm Rigid Insulation		
2x4 framing	8.40	
apply rigid insulation	6.98	
insulating	2.33	17.71
3- 2X6 @ 400mm O/C		
2x6 framing	7.32	
sheathing	5.43	
insulating	2.58	15.33
4- 2X6+2X3 Horizontal Strapping		
2x6 wall as above	15.33	
apply horizontal strapping	3.61	
insulating	2.33	21.27
5- ECOSTUD		
Ecostud framing	8.75	
sheathing	5.43	
insulating	5.16	19.34
6- 2X4+LARSEN-TRUSS		
2X4 wall as above	16.15	
row of back blocking	1.64	
frame & attach Larsen-truss	6.00	
insulating	2.84	26.63
7- DOUBLE STUD		
2x4 @ 600mm o/c	8.40	
2x4 @ 400mm o/c	8.40	
sheathing	5.43	
bracing	2.79	
insulating	6.99	32.01

++++ MATERIAL COST BREAKDOWN ++++

	ITEMISED	TOTAL
1-2X4 Conventional Wall		
Plate	1.43	
studs	3.38	
FG insulation RSI 2.1	4.51	
Sheathing	6.38	
Poly	0.70	16.40
2- 2X4+50mm Rigid Insulation		
Plate	1.43	
studs	3.38	
FG insulation RSI 2.1	4.51	
50mm Rigid Insulation	9.79	
Poly	0.70	19.81
3- 2X6 WALL @ 600mm O/C		
Plate	2.86	
studs	3.67	
Sheathing	6.83	
FG insulation RSI 3.5	7.74	
Poly	0.70	21.80
4- 2X6+2X3 HORIZONTAL STRAPPING		
2x6 wall as above	21.80	
2x3 strapping	2.06	
FG insulation RSI 1.4	3.47	27.33
5- ECOSTUD ESC-3:3		
Ecostuds	7.50	
Ecoplates	2.50	
2x4 Cap plate	0.48	
Sheathing	6.38	
FG insulation 2RSI 3.5	15.48	
Poly	0.70	33.04
6- 2X4+LARSEN-TRUSS		
2x4 Wall as above	16.40	
Larsen-Truss	7.19	
Blocking + plywood plate	0.85	
FG insulation RSI 3.5+1.4	11.20	35.64
7- DOUBLE STUD		
2x4 plate	2.86	
2x4 studs	6.75	
Sheathing	6.83	
FG insulation 2RSI 2.1	9.02	
FG insulation RSI 3.5	7.74	
plywood headers	2.09	
Poly	0.70	35.99

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5- MEANS COST DATA

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2- D. Gordon Howell, P. Eng., Alberta Research Council.

3- David F. Begin, P. Eng., Ecostud Building Products, Edmonton.

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5- John Larsen, Sunscape Bui'ders Ltd., Edmonton. Larsen-Truss builder.

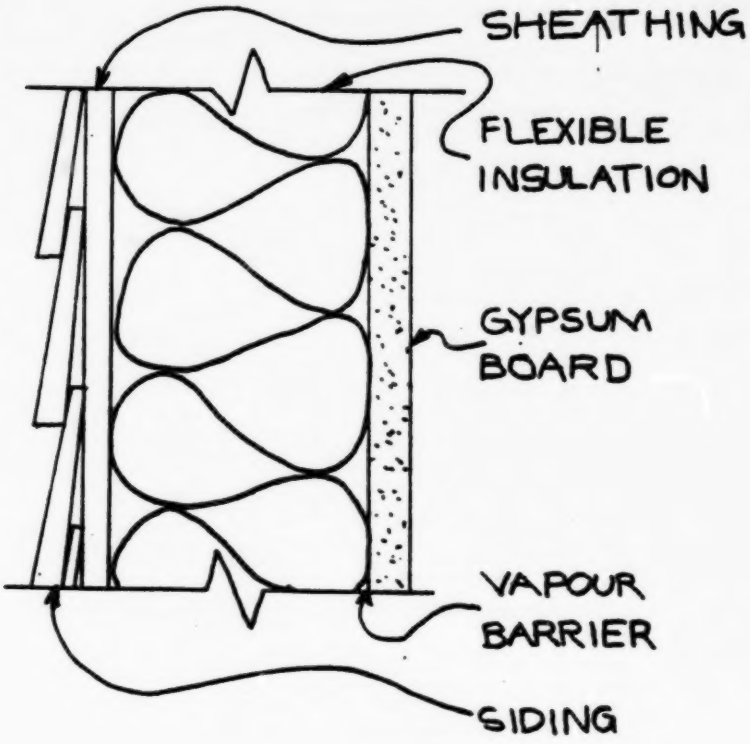
6- John Hughes, Passive Solar Designs, Edmonton. Larsen-Truss designer.

APPENDIX CC-3

DIAGRAMS WITH INSULATION CALCULATIONS

CONVENTIONAL 2X4 (38X89)	Figure 1
CONVENTIONAL 2X4+50mm RIGID INSULATION	Figure 2
2X6 (38x140)	Figure 3
2X6+2X3 Horizontal Strapping	Figure 4
ECOSTUD	Figure 5
2X4+LARSEN-TRUSS	Figure 6
DOUBLE STUD WALL	Figure 7

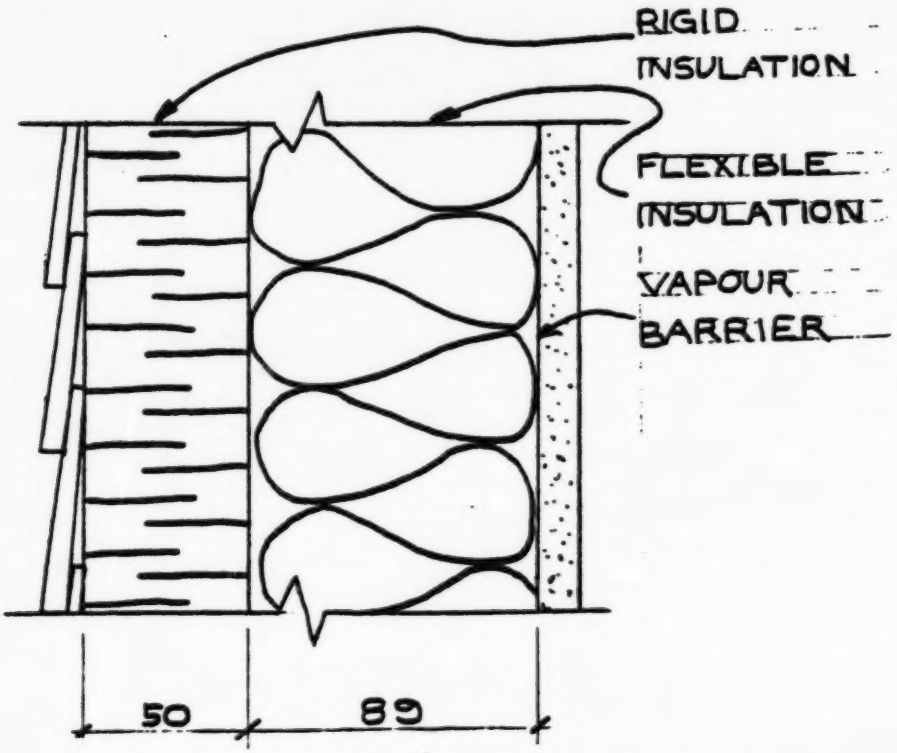
STANDARD 38 x 89



DESCRIPTION	THICKNESS	RSI
OUTSIDE AIR FILM	-	0.03
BEVEL LAPPED WOOD	12 mm	0.14
PLYWOOD	7.5 mm	0.07
FIBRE GLASS	89 mm	2.11
GYPSUM BOARD	13 mm	0.08
INSIDE AIR FILM	-	0.12
		2.55

FIG #2

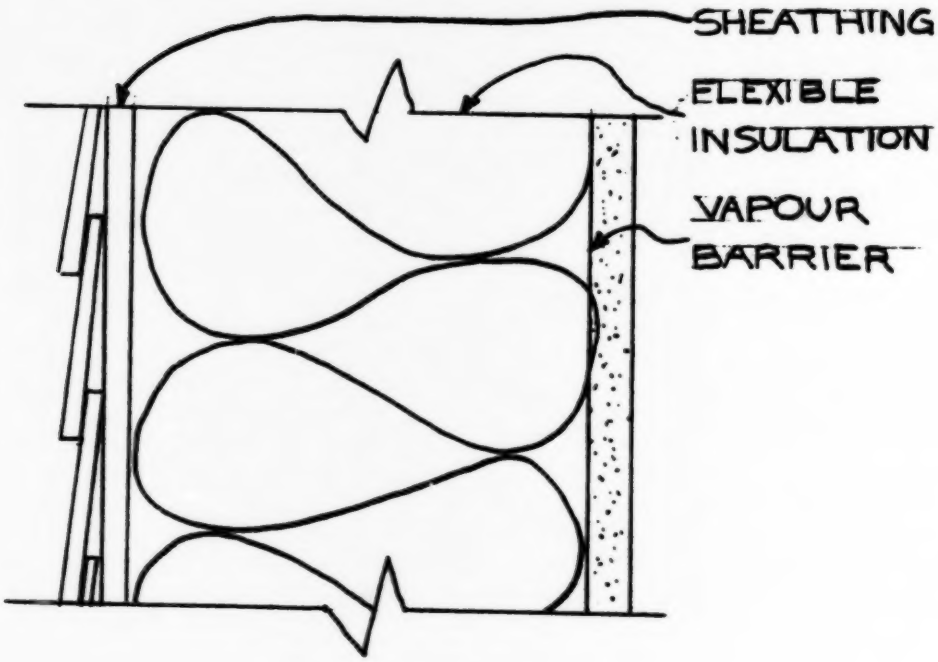
STANDARD 38x89 +STYRO-SM



DESCRIPTION	THICKNESS	RSI
OUTSIDE AIR FILM	-	0.03
BEVEL LAPPED WOOD	12mm	0.14
RIGID INSULATION	50mm	1.28
FIBREGLASS	89mm	2.11
GYPSUM BOARD	13mm	0.08
INSIDE AIR FILM	-	0.12
		3.76

FIG # 3

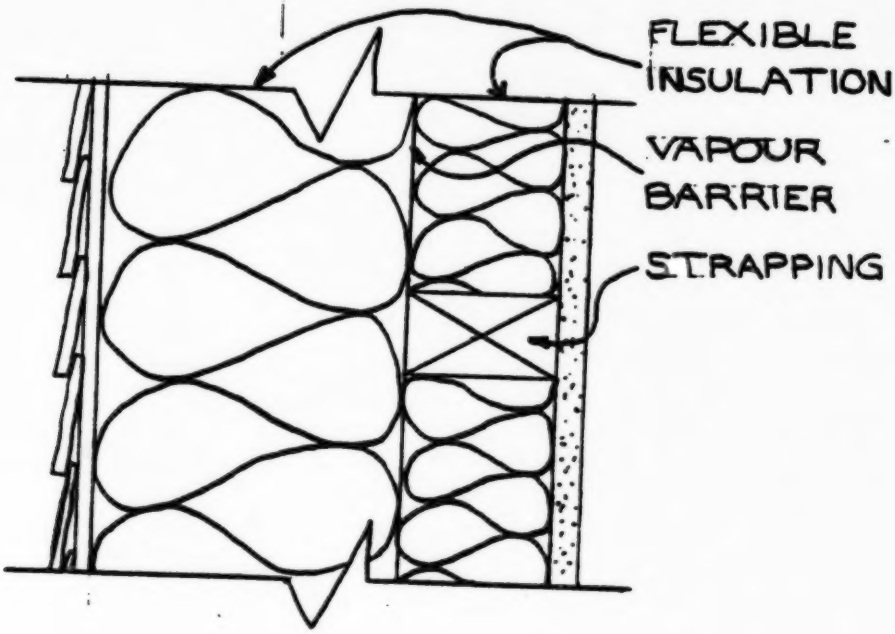
38 x 140 STUD



DESCRIPTION	THICKNESS	RSI
OUTSIDE AIR FILM	-	0.03
BEVEL WOOD SIDING	12 mm	0.14
PLYWOOD	7.5 mm	0.07
FIBREGLASS	140 mm	3.50
GYPSUM BOARD	13 mm	0.08
INSIDE AIR FILM	-	0.12
		3.94

FIG #4

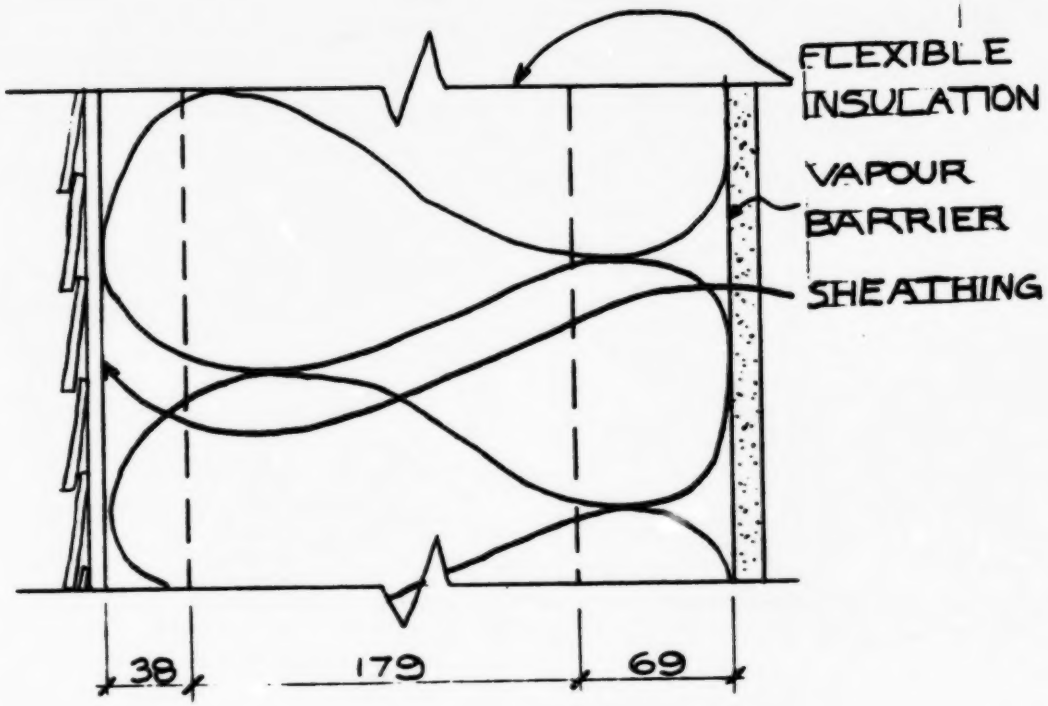
38 x 140 + 38 x 63 STRAPPING



DESCRIPTION	THICKNESS	RSI
OUTSIDE AIR FILM	-	0.03
BEVEL WOOD SIDING	12mm	0.14
PLYWOOD	7.5mm	0.07
FIBREGLASS	140mm	3.50
FIBREGLASS	63mm	1.40
GYPSUM BOARD	13mm	0.08
INSIDE AIR FILM	-	0.12
		5.34

FIG # 5

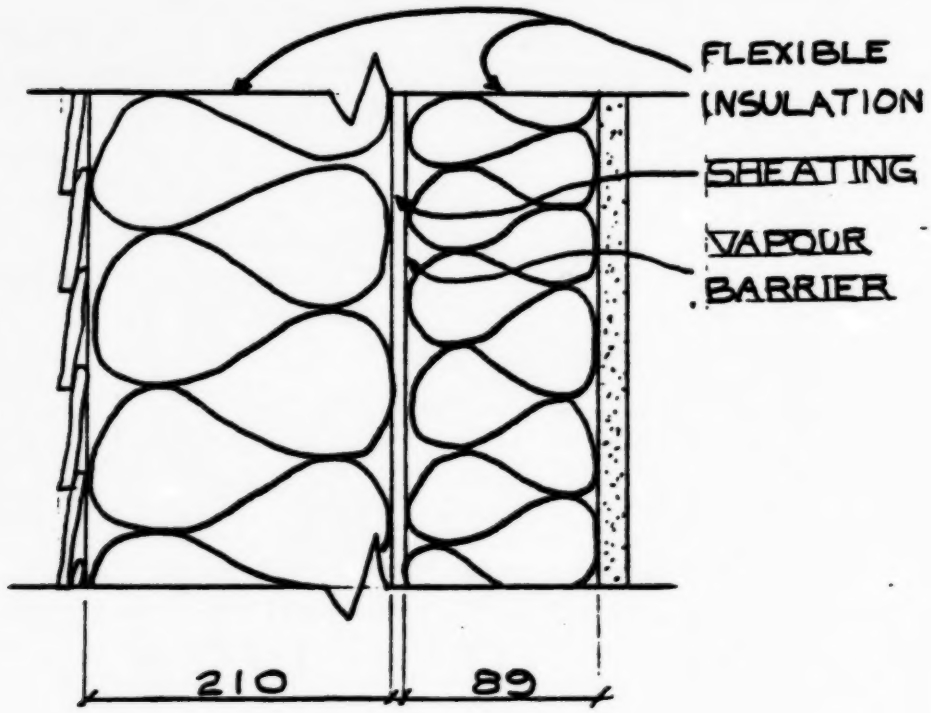
ECOSTUD



DESCRIPTION	THICKNESS	RSI
OUTSIDE AIR FILM	-	0.03
BEVEL WOOD SIDING	12mm	0.14
PLYWOOD	7.5mm	0.07
FIBREGLASS	286mm	7.0
GYPSUM BOARD	13mm	0.08
INSIDE AIR FILM	-	0.12
		7.44

FIG # 6

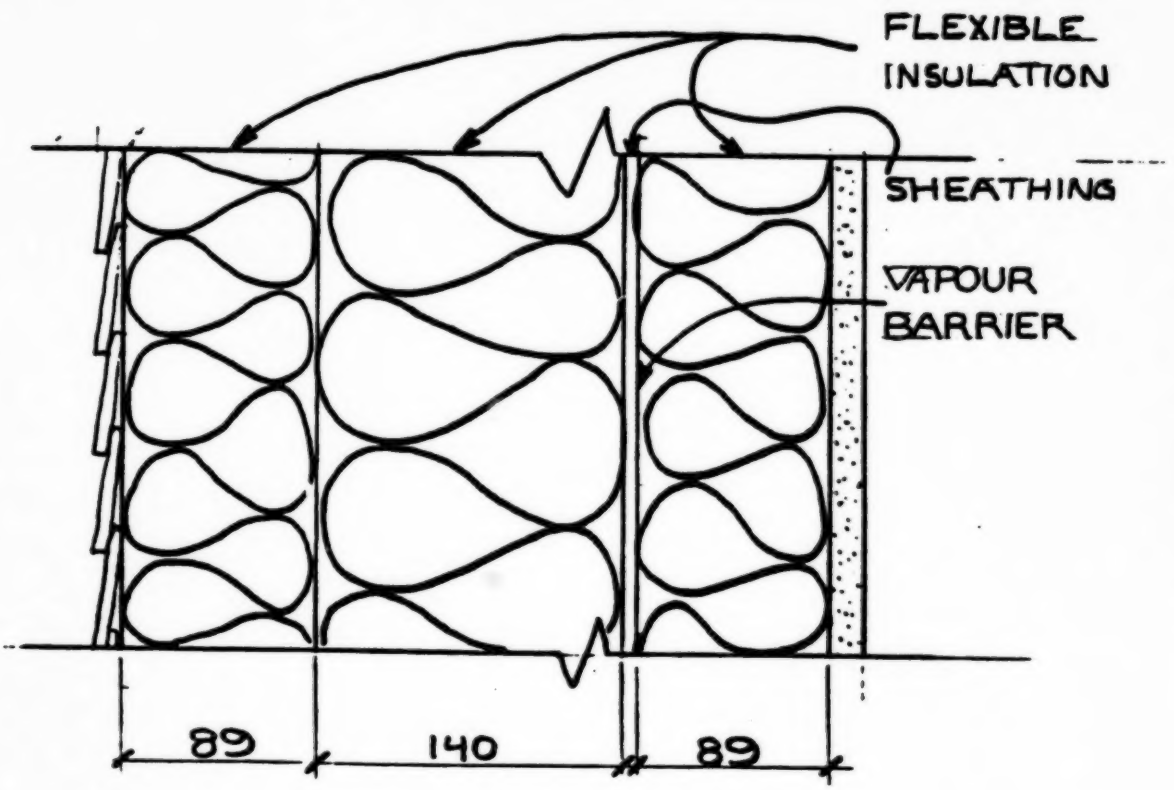
LARSON TRUSS + 38 x 89



DESCRIPTION	THICKNESS	RSI
OUTSIDE AIR FILM	-	0.03
BEVEL LAPPED SIDING	12 mm	0.14
FIBREGLASS	210 mm	4.90
PLYWOOD	7.5 mm	0.07
FIBREGLASS	89 mm	2.11
GYPSUM BOARD	12 mm	0.08
INSIDE AIR FILM		0.12
		7.45

FIG #7

DOUBLE 38 x 89 STUD WALL



DESCRIPTION	THICKNESS	RSI
OUTSIDE AIR FILM	-	0.03
BEVEL LAPPED WOOD	12 mm	0.14
FIBREGLASS	89 mm	2.11
FIBREGLASS	140 mm	3.5
PLYWOOD	7.5 mm	0.07
FIBREGLASS	89 mm	2.11
GYPSUM BOARD	13 mm	0.08
INSIDE AIR FILM	-	0.12
		8.16

POOR

QUALITY

ORIGINAL